RUDIMENTARY TREATISE

ON

WELL-DIGGING, BORING,

AND

PUMP WORK.

WITH ILLUSTRATIONS.

BY JOHN GEO. SWINDELL, C.E.

*Price One Shilling.*

# MR. WEALE'S

## NEW SERIES

### OF

# RUDIMENTARY WORKS FOR BEGINNERS.

GEOLOGICAL MAP OF SOUTH EASTERN CHALK RANGE, OF ENGLAND.

A | Chalk.

B | London Clay.

C | Chalk Marle &
     Green Sand.

D | Weald Clay.

E | Iron Sand.

F | Plastic Clay.

G | Upper Marine.



Bury St Edmunds
Sudbury
Thaxted
Colchester
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Tunbridge Wells
Hastings
Rye

Aldershot
Bagshot
Holmesly
Horsham
Lewes
Beachy Hd

Line of Section

Basingstoke
Alton
Nutley
Petersfield
Worthing
Brighton
Shoreham
of Plate 2.

Salisbury
Botley
Southampton
Portsmouth

Wareham
Brighton
I. of Wight

# RUDIMENTARY TREATISE

ON

# WELL·DIGGING, BORING,

AND

# PUMP·WORK,

ETC., ETC., ETC.

BY

JOHN GEO. SWINDELL, R.I.B.A. ASSOCIATE,

CONSULTING ENGINEER.

WITH SIXTEEN ILLUSTRATIVE PLATES.

# PREFACE.

THE following Treatise must be regarded as an attempt to condense a general practical view of the many subjects connected with Well-work: it would have been easy to enlarge any of them, but to have done so would necessarily have entailed a corresponding loss of matter in reference to the others. To avoid this on the one hand, and a mere superficial uninstructive glance on the other, has been the Author's aim. In furtherance of this object, the remarks on executed work, contained in the last chapter, have been added. These precedents show at a glance methods of detail and arrangement which, if remarked on generally, would occupy much greater space ; they also form a nucleus for observations, which could only be brought forth by a long process of reasoning in any other manner : again, they serve to bind and connect together, by their very particularity, considerations which otherwise might pass unheeded, on account of their now apparent applicability. The Illustrations which refer to the works at Hampstead and Kingsbury were specially prepared for this purpose, as conducing by their completeness to impress on the mind of the reader the ideas conveyed in the text. The drawings of the boring tools represent those of a well

known contractor, and were originally obtained by Mr. Weale
to append to an account of the well sunk at the New Model
Prison, which was executed under the superintendence of
Lieutenant-Colonel Jebb.   The author's thanks are due to
those gentlemen who have charge of the various wells he has
visited, for their kindness in aiding him and giving him access
to the works.

<div align="right">J. G. S.</div>

3, Kilburn Priory,
   January 1, 1849.

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# RUDIMENTARY TREATISE.

# WELLS AND WELL-DIGGING.

## CHAPTER I.

### PRELIMINARY OBSERVATIONS.

THE practice of obtaining water from wells is of great antiquity : many that we have accounts of in the Scriptures were doubtless mere excavations in the sides of rocks and hills, where springs of water were plentiful; in many cases they were of the principle now called Artesian, the water rising in the excavation so near the surface as to be reached by suspending into it a bucket attached to the end of a short rope. In parts of Greece, where this plan for raising water was common, the orifice of the well was often finished with a cylindric curb of marble, which sometimes was beautifully carved. Although the principle of well-sinking is unchangeable, the practice is by no means so ; indeed, within the last few years a great change has taken place, both as regards their mode of construction and materials : as now practised, they may be divided into two classes—Artesian, and the common or ordinary sort. The former are so named, as having in their construction the operation of boring exercised, which practice was anciently carried on with great success in the province of Artois, in France : these differ from common excavated wells in not being dug, necessarily of a large diameter, into the spring itself, but] to a certain distance above the spring ; deep enough, however, for the water to rise into them when the reservoir containing it is perforated by the boring

tool; the bored hole, being only of a small diameter, is for the purpose of conducting the water from the spring into the well. It is easy to conceive that, in any case where boring for water is attempted, the water must lie under some impermeable strata, of a basin-like structure, for if such disposition exists, it follows naturally that, when this strata is perforated, the water will rise to a height corresponding to the hydrostatic pressure (see Fig. 4, Plate 1). The Artesian well completed a few years back at Grenelle, near Paris, may be referred to as an example of perseverance and faith in the principle. The depth of the bore hole was 1800 feet; the imprisoned water, on being tapped, rose with prodigious force, and overflowed the surface in immense quantities. The application of boring opened a vast field for the operations of the well-sinker; districts apparently badly supplied with water were found to have, at distances from the surface precluding the carrying on a common well, on account of its expense, quantities of water pent up, and which only required perforation, to allow them to rise either to the surface of the ground, or to within such a distance of it as to be easily arrived at by sinking a common well, at a comparatively trifling expense. By neglecting the peculiar circumstances attendant in all cases where boring for water is successful, many disappointments have arisen and great expense has been incurred, for what after all reasonably could not have been expected. The first operation of boring the author ever witnessed was of this description; he remembers, when a very little boy, watching the work at a brewery in the town in which he lived, and, moreover, of being rather frightened by the same, as, according to the expectation of the townsfolk, the water was to overflow the surface in quantities sufficient to drown those near, unless they were very nimble, when it suddenly should break upon them: in spite of these predictions, the work was abandoned, and well it might be; the place was situated at the *escarpment of the* chalk hills, forming part of the boundary of *the London basin.* Plenty of water was to be found, it is true,

by sinking deep wells into the chalk, but as no hydrostatic pressure of water existed at that, the upper, part of the basin, no rise of water to any extent, much less any overflow of the surface, could be anticipated ; had the chalk and blue marl been perforated, the and springs underneath would have no doubt supplied vast quantities of water ; but its rise, even in this case, would have been problematical. The history of boring is involved in ambiguity ; it is an art anciently practised—this we have sufficient evidence of ; but, nevertheless, the art was nearly lost. The practice has been resuscitated within the last century, and is so greatly increased, that now it is common to all parts of the civilized globe, and is applied to a variety of different purposes. In Egypt, Syria, and various parts of the East, are remaining examples of ancient Artesian wells, the waters of which overflow the surface: the precise manner of executing, and lining the bore holes of these wells is not known. The Chinese have long used them, and though the period of their introduction into China is unknown, the probability is that they are of great antiquity.

A French missionary, the Abbé Imbert, relates that, when in China, he had seen many bored wells, of a diameter of five or six inches, and a depth of from 1500 to 1800 feet. The following is the substance of his account, given in a French work, called " Guide du Sondeur, ou Traité Théorique et Pratique des Sondages, par M. J. Degousée :"—" There exist in the canton of Ou-Tong-Kiao many thousand wells, in a space of ten leagues long by five broad. These wells cost a thousand and some hundred taëls (the taël is worth seven francs fifty cents). These wells are from 1500 to 1800 feet in depth, and of a diameter from five to six inches ; to bore these, they commence by placing in the earth a wooden tube of three or four inches diameter, surmounted by a stone edge, pierced by an orifice of five to six inches ; then in the tube a trepan is allowed to play, weighing three or four hundred pounds. A man mounted on a scaffold swings a block, which raises the trepan two feet high, and lets it fall by its own

weight. The trepan is secured to the swing lever by a cord made of reeds, on which is attached a triangle of wood; a man sits close to the cord, and at each rise of the swing seizes the triangle and gives it a half turn, so that the trepan may take in falling another direction. A ˍˍˍˍˍ ˯ˍ ˯ˍˍˍˍˍˍ workmen ˍˍˍˍˍ ˍˍˍˍˍ ˍˍ ˍˍˍˍˍ, ˍˍˍ ˍˍˍ work goes on day and night: they are sometimes three years in boring the wells to the requisite depth. These wells nearly always emit a great deal of inflammable air, and there are some which furnish nothing else but gas; these they call fire wells: it appears the Chinese employ these for supplying combustible gas, which is, without doubt, carburetted hydrogen, such as proceeds from coal mines." If it is as Mr. Imbert supposes, but who is probably mistaken in his calculation, some of these wells are as much as 3000 feet in depth. Further on, a system of boring, in which the torsion of the rope alone is sufficient for changing the position of the tool, is described; this is called the Chinese system, and is nearly identical with the above description. Documentary evidence as to the practice of boring for water is scarce. The first mention of it in France is found in a treatise by Belidor, on the Science of Engineering, published in the year 1729. Ancient bored wells are found at Artois, in France, the precise date of execution being unknown; and in that province they are made very easily, and with little expense. Boring for water was practised in England, as a preliminary or feeling operation,—in other words, in advance of the digging,—for a long time before the Artesian principle was recognised. For instance, in the year 1793, Mr. Munday's well at Chelsea was executed, and the workmen bored in advance of their digging about twenty feet; so again at Mr. Vuliamy's, Norland House, after having dug, as an ordinary well, to the depth of 236 feet, he bored and inserted a copper pipe, five inches and a quarter diameter; after boring twenty-four feet the spring was tapped, and the water rose 243 feet in one hour and twenty minutes. The sand also *blew into the well* ninety feet, thus choking to a great extent

the flow of water; by clearing some of this away, the water overflowed the surface at the rate of forty-six gallons per minute : this occurred in the year 1794. It is evident that, in this example, had the advantage of boring been fully appreciated, and the geological situation of the place been accurately determined, much needless expense in well-sinking would have been saved.

In addition to its use in operations of well work, boring is of service in a variety of ways; for mining purposes, railway works, examination of ground, such as in the case of a doubtful situation, testing morasses, and other such works. The reasonableness of its application is self-evident; a few pounds spent in boring, may save hundreds, which would be expended if the operation were to be neglected. The accounts that are sometimes given of the quantities of ground swallowed up in filling a morass, so as to form a railway embankment, will occur to all, as so much waste of material and labour. Generally, after a sufficient quantity of earth has disappeared to make the work appear of a very serious character, a different method of proceeding is adopted. Now, by boring in the first instance, so as to ascertain the nature exactly of the ground to be passed over, at once the right method of getting over the difficulty would be applied.

We find Sir C. Wren did not neglect the precaution of boring in a part of the ground under St. Paul's, the stability of which he doubted. This fact is noticed by Davy, in his work on Artificial Foundations, and is thus described by him in an extract from the Parentalia :—" In the progress of the works of the foundations, the surveyor met with an unexpected difficulty. He began to lay the foundation from the west end, and had proceeded successfully through the dome to the east end, where the brick-earth bottom was very good ; but as he went to the north-east corner, which was the last, and where nothing was expected to intercept, he fell, in prosecuting the design, upon a pit where all the pot-earth had been robbed by the potters of old time. It was no little perplexity to fall into

this pit at last; he wanted but six or seven feet to complete the design, and this fell in the very angle, north-east. He knew very well that under the layer of pot-earth, there was no other good ground till he came to the low-water mark of the Thames, at least forty feet lower; his artificers proposed to him to pile, which he refused; for, though piles may last for ever when always in water, otherwise London Bridge would fall, yet, if they are driven through dry sand, though sometimes moist, they will not. His endeavours were to build for eternity; he therefore sunk a pit of about eighteen feet square, wharfing up the sand with timber, till he came, forty feet lower, into water and sea shells, where there was a firm sea beach, which confirmed what was before asserted, that the sea had been in ages past where St. Paul's now is. He *bored* through this beach, till he came to the original clay: being then satisfied, he began from the beach a square pier of good solid masonry, ten feet square, till he came within fifteen feet of the present ground; then he turned a short arch underground till he came to the former foundation, which was broken off by the untoward accident of the pit."

The application of boring to the practice of pile-driving, has, in France, been attended with great success, and with a smaller expense than when carried on in the ordinary manner; but it is evident it is only economically applicable where a certain degree of difficulty exists in driving by the monkey in the usual manner. In the "Guide du Sondeur," &c., before alluded to, is an account of the boring operations carried on in fixing the posts for the Electric Telegraph from Paris to Versailles; 476 of these were fixed in their places in the course of a month; they averaged in price 3fr. 50c. each, some being executed through hard rock. Boring is applicable either under water or on dry land, either in a vertical, horizontal, or inclined direction; and though its cheapness is apparent when the hole is comparatively small, yet even is it sometimes practised *of a diameter* of many feet, the situation not admitting of *excavation. Such a case* as the above is often to be met with

in well work; thus, in sinking iron cylinders through sand charged with water, the water must either be pumped out, or the sand bored through. The latter will always be chosen where the rush of water is great, or when the pumping becomes expensive. To enumerate every case in which boring can be successfully applied, would be useless; its capability for various purposes being shown, circumstances will dictate its application, whether to wells for draining, mining, building, or purely scientific purposes. In carrying on boring and well work, a great deal of practical information applicable in other operations, and interesting in reference to the one going on, is embodied by keeping a correct journal. The one here given is copied from a Model Journal, by M. J. Degousée; and had such a journal been always kept during the execution of the numerous wells lately executed in the neighbourhood of London, by comparing them, much valuable geological information, and certain questions relative to the rise of water in wells, might have been ascertained with greater accuracy than hitherto. When a well is merely dug, of course the columns relating to boring tools may be omitted, and when boring does take place, the list must be sufficiently extensive to embrace all the tools likely to be used. In the accompanying form the columns are filled up nearly at random, but sufficiently in detail to show how such a journal may be kept. Boring rods have usually their lengths numbered on them, so that, if carefully screwed together in their proper order, the depth of the hole may be readily determined at all times.

**JOURNAL OF BORING at a search for being**

| No. of sorts or samples of Ground. | Days of 1848. Rest | Days of 1848. Work | NATURE OF THE EARTH. | Chisel | Auger | Shell | Spring Rymer | Latch or recovering Tool. | Thickness bored at the end of each day. | Depth of Boring at the end of each day. | Thickness of each of the Strata. | Distance of Water in Well to surface of Earth. | OBSERVATIONS. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | December 16th | Surface soil | ... | ... | ... | ... | ... | 9 0 | 9 0 | 3 0 | | Commencement of digging—[diameter. |
| 2 | ... | | Clayey soil | ... | ... | ... | ... | ... | | | 2 0 | | |
| 3 | ... | | Fine sand | ... | ... | ... | ... | ... | | | | | Finish of digging, Fixing guiding pipe for boring |
| 4 | ... | 17th | Ditto | 6 | ... | 6 | ... | ... | 4 6 | 13 6 | 8 6 | | |
| | | 18th | Flint stones | 6 | ... | 6 | ... | ... | 2 0 | 15 6 | | | |
| | | 19th | Ditto | 8 | 8 | 7 | ... | ... | 3 0 | 18 6 | 5 0 | | |
| | | 20th | Ditto | 1 | | 2 | ... | ... | 2 0 | 20 6 | 2 0 | | |
| | | | Marl | ... | ... | ... | ... | ... | | | | | |
| 5 | 21st | | ... | ... | ... | ... | ... | ... | ... | ... | | ... | Holiday. |
| | | 22nd | Marl | 2 | 2 | ... | ... | ... | | | | | |
| 6 | ... | 23rd | Gray marl and calcareous lamina | ... | 1 | 3 | ... | ... | 9 0 | 29 0 | | | |

# CHAPTER II.

## THEORY OF SPRINGS.

THE theory of springs has given rise to much discussion: the
limits of this work will not suffice to examine in detail all the
ideas that, at various times, and by different people, have been
broached on the subject, some partially true, applicable in
certain cases, and some extremely absurd. That which will
generally account for water flowing from springs, is the con-
sideration that they are lines of natural drainage; in other
words, are supplied by the rain, hail, snow, and vapour
precipitated on the earth's surface, and part of which is
absorbed thereby. A vast circulation of water is thus kept
up. The rivers and streams supplied by the springs, in
their turn supply the sea, which, together with the water
generally, supplies by natural evaporation the atmosphere,
thus completing the circuit. Though it has never been
denied that land springs, that is, springs found near the sur-
face of the ground, are supplied by rain,—for the fact speaks
for itself, inasmuch as that in dry weather they often cease
flowing—yet that deep well springs are supplied from the
same source has been controverted; for, say the objectors,
how is it that an increase of rain apparently makes no dif-
ference to the quantity of water, and, in like manner, great
drought appears not to affect them? A satisfactory answer
to this will be found on examination of the conditions affecting
such springs; it will be seen they are generally reservoirs of
porous matter interposed between impermeable strata, which
reservoirs will naturally overflow at the points where the
components of the porous matter, supposing it to assume a
basin-like form, touch the surface of the ground; these
overflows form rivulets and streams, and the effect of great
rain or drought will only be to add to, or diminish, the
quantity discharged by these natural channels; making but
little difference in the height of the level of the water in the

B 3

main reservoir itself. I say but little, as careful experiments have shown that a slight difference does generally exist, according to the different seasons of the year. A partial examination of the strata of a district has led some parties to imagine that springs cannot be fed by rain falling on the earth's surface, because the surface of the ground is separated from the spring by clayey or rocky strata, and therefore impervious to water. This objection is of no weight, for it does not follow that because the main spring is supplied by absorption from the earth's surface, that therefore the rain must soak into it vertically, any more than in the case of a common rain-water tank, where the water is conducted by pipes from the collecting to the receiving surface. Now, by substituting for conducting pipes, porous strata between impervious, and establishing that the porous strata, at some point or points, are exposed to the rain, the simile becomes complete. That this case is not a fancied one, refer to Plate 2, where it will be seen that the London clay is the impervious strata, and that the rain which falls on the uncovered portions of the chalk, and the sands of the plastic clay formation, is conducted by the porous sand and chalk under the clay, where it accumulates ; for the impermeable plastic clay holds the water in the sand from the chalk, and the impermeable strata under the chalk causes the lower portions of that formation to be fully saturated with water also, as far as the hardness of the material will allow it to be. Another question has arisen, as to whether sufficient rain falls to alone supply all rivers, springs, &c., assumed above to be so supplied. From a mean of a variety of experiments, it has been found that the annual depth of rain which falls in England and Wales is about 31 inches, supposing the same collected on the surface of the ground, allowing none to soak in, and none to evaporate. In like manner, the depth of dew has been found to be five inches. The whole may, therefore, be assumed as thirty-six inches. Of this quantity, part is *disposed of in the* supply of rivulets, springs, &c., and part

is again raised directly into the atmosphere by evaporation.
Assuming that two-thirds go in this manner, we have still
twelve inches deep for the supply of the rivers and springs, a
quantity as follows:—The surface of England and Wales
being 49,450 square miles, we have 5280 ft. × 5280 ft.
× 49,450 sq. m. = 1,378,586,880,000 square feet of surface;
one foot in depth of water will change the above to cubic
feet; so much for the supply. Now it has been calculated
by Dr. Dalton that the Thames drains a tract of country of
the area of 600 square miles, or about one-eighth of the area
of the whole, so that, if it be possible to calculate the water
annually discharged into the sea by the Thames, a rough
approximation to the total expenditure of water can be arrived
at. By some philosophers, who have paid attention to the
subject, it has been calculated that the river Thames dis-
charges daily 13,000,000 tons of water, which, multiplied by
35.84, the number of cubic feet in a ton, = 465,920,000 cubic
feet; this, again multiplied by 365, equals 170,060,800,000
cubic feet, the quantity annually discharged into the sea by
the Thames alone; eight times that quantity, according to the
above assumption, or 1,360,486,400,000 cubic feet, will
therefore equal the total annual expenditure of the rivers of
England, an amount not quite equal to the supply by the
rain and dew, the difference in favour of the supply being
1,378,586,880,000 − 1,360,486,400,000 = 18,100,480,000
cubic feet. From what has been said, there can be no doubt
that in this country the rain and dews alone are quite suffi-
cient to account for the flowing of all the springs; and analogy
would lead us to suppose that in all countries similar causes
would occasion like results. The following, from Rees's
Cyclopædia, Art. "Spring," will show that the above considera-
tion has been discarded by some. The quotation must be re-
ceived with great caution, as the theory proposed is purely
imaginative, and in a majority of cases direct proof can
be adduced that it is incorrect: "Other naturalists, therefore,
have had recourse to the sea, and derive the original of

springs immediately thence; but how the sea water should be raised up to the surface of our earth, and even to the tops of the mountains, is a difficulty in the solution of which they cannot agree. Some fancy a kind of hollow subterranean rocks to receive the watery vapours raised from channels communicating with the sea, by means of an internal fire, and to act the part of alembics in freeing them from their saline particles, as well as condensing them, and converting them into water. This kind of subterranean laboratory was the invention of Descartes."

To advance that all and every spring on the globe is derived from surface drainage alone, is equally as untenable as to adopt the above quoted theory; some, by their brackish flavour, at once bespeak their direct oceanic origin. It is highly probable that some fresh water springs do receive a supply from, and are modified by, the waters of the sea, derived therefrom by capillary action. When the sea rests on porous matter, as chalk, no reason can be given why the water should not be absorbed by it, and affect to a certain extent the quantity and quality of drainage water which may be held in the same chalk reservoir; and this more especially when the water level of the springs is at or even below the level of the sea. It is natural to suppose this action would be felt to the greatest extent near the sea itself—a supposition borne out by facts. At this present time a well is being sunk at Newhaven, in the chalk, by the London, Brighton, and South Coast Railway Company, and the works are seriously affected by the percolation of the sea water. Reference to a geological map will show that those same chalk hills, as well as others abutting on the sea, are continued without interruption to the main chalk range on the western side of the London basin; therefore, in a modified degree, the percolating action of the sea water must be felt in all parts of the basin at or near the level of the sea; and which are not cut off from this action by any uplifting of the strata under the chalk, as in *Fig. 1, Plate 1, no direct* cutting off of the chalk by any out-

cropping strata taking place from the sea to the chalk range above mentioned. Plate 2 might seem to contradict the above, an outcropping of the impervious strata taking place between the chalk under London and Newhaven ; this section is taken in a line between the two places. A reference to Plate 3, which is copied from part of Messrs. Conybeare and Phillips's geological map, shows this line of section, as also the direct communication, though not in a straight line, between the chalk of Newhaven and the range on the western and north-western side of the basin. The lower portions of the chalk are extremely dense, almost impervious, but not quite, so that a possible though much choked communication between the sea and springs derived from the rain being thus established, we may expect to find in such water, in a diluted state, such salts as the sea abounds in, due allowance being made for various decompositions that these salts must necessarily undergo during the progress of their filtration. Sea water, according to an analysis of Dr. Murray, contains muriate soda, muriate magnesia, sulphate magnesia, sulphate of lime. Water drawn from the well at the Hanwell Lunatic Asylum contains muriate soda, sulphate of lime, carbonate of soda, carbonate of lime, and a trace of iron. From this we see that two of the ingredients of sea water, though much diluted, exist in this fresh, in addition to other salts which the spring water has gathered during its percolation. Representing the salts as decomposed, the comparison becomes more striking :

Sea water $\begin{cases} \text{Lime,} \\ \text{Soda,} \\ \text{Sulphuric acid,} \\ \text{Muriatic acid,} \\ \text{Magnesia.} \end{cases}$ Spring water $\begin{cases} \text{Lime,} \\ \text{Soda,} \\ \text{Sulphuric acid,} \\ \text{Muriatic acid,} \\ \text{Carbonic acid,} \\ \text{Trace of iron.} \end{cases}$

The above conclusion would be discarded altogether if the compact nature of the chalk alone were considered; but granting it to be very slightly pervious, intersected by fissures

and lines of flints, around which lines an increased permeability is always found—granting this, which, indeed, cannot be disputed, the possibility of the above is obvious.

The theory which supposes the springs supplied by rain, hail, dew, snow, &c., which originally are raised into the atmosphere by evaporation, is now allowed to be correct by all whose opinion is of any value. That till comparatively within a few years the discussion should have been unsettled, is not to be wondered at. Till geology showed, by explaining the nature of the crust of the earth, the natural channels for subterranean currents, and till accurate experiments had determined the immense extent of natural though unseen and unfelt evaporation, no decisive proof could be given to settle and determine the question. Science has, however, now so far advanced that we can recognise the cause and the means whereby the alternate exhaustion and replenishment of the subterranean reservoirs are accomplished.

Before illustrating more particularly the various circumstances affecting the supply of water to springs, some of the most remarkable may be mentioned; and among them, the hot springs of Iceland claim attention. One of these, called the Great Geyser, is thus described :—The fountain is situated in a circular mound of matter, deposited by the water itself during the lapse of ages. In the centre of this basin a perpendicular inlet, about ten feet diameter, descends into the earth, and communicates with the supply. The basin is usually covered, to a depth of about four feet, with clear hot water, which flows away by two passages situated in the sides of the basin. At the time of eruption, which occurs at intervals, the first signal is a rumbling noise and low report; after which a few jets of water are thrown up; the jets become higher, and the noise becomes louder, till at last a defined jet, fifty to a hundred feet high, is formed, and of a diameter equal to the main inlet; the eruption seldom lasts longer than a few minutes, and they occur at irregular intervals, seldom *exceeding many hours.* The water has the property of in-

crusting with mineral matter, objects over which it flows, also covering the parts round about it with silicious incrustations.

The account of the two following springs are copied into Rees's Cyclopædia from the Philosophical Transactions :—
" In the diocese of Paderborn, Westphalia, there is a spring which disappears twice in twenty-four hours, and always returns at the end of six hours, with a great noise, and with so much force as to turn three mills not far from its source. It is called the Bolder Horn, or Boisterous Spring." Again, " At Boseley, near Wenlock, in Shropshire, there is a famous boiling well, which was discovered in June, 1711, by an uncommon noise in the night, so great that it awakened several people, who, being desirous to find what it was owing to, at length found a boggy place under a little hill, not far from the Severn, and perceiving a great shaking of the earth and a little boiling up of the water through the grass, they took a spade, and digging up some part of the earth, the water flew to a great height, and was set on fire by a candle. This water was for some time afterwards constantly found to take fire, and burn like spirit of wine ; and after it was set on fire, it would boil the water in a vessel sooner than any artificial fire, and yet the spring itself was as cold as any whatever.    This well was lost for many years, and not recovered till May, 1746, when, by a rumbling noise underground like to that the former well made, it was hit upon again, though in a lower situation and thirty yards nearer the river ; the well is four or five feet deep, and six or seven wide ; within that is another less hole of like depth, dug in the clay, at the bottom of which is placed a cylindric earthen vessel of four or five inches' diameter at the mouth, having the bottom taken off, and the sides well fixed in the clay rammed close about it. Within the pot is a brown water, thick as puddle, continually forced up by a violent motion, beyond that of boiling water, and a rumbling hollow noise, rising and falling by fits five or six inches ; it may be fired by a candle at a quarter of a yard distance, and it darts and flashes in a

violent manner about half a yard high; it has been left
burning forty-eight hours without any sensible diminution."
It is needless to remark, the above phenomenon has nothing
to do with the water at all, the effect being entirely owing to
a portion of gas which the water holds mixed with it.

The manner in which the rain water is conducted to the
springs, and the circumstances affecting the same, are very
simple in reality, but in appearance complicated. The general
principle may be gathered from Plate 2, which section of the
London basin was before referred to. The water which falls on
the London clay not being absorbed by it, is necessitated to flow
off as surface drainage; that, however, which falls on the un-
covered portions of the chalk, and sand intermixed with the
plastic clay, and on the gravel which in many places overlies
the chalk, does not run off as surface streams, but is absorbed
by the porous strata which thereby become saturated, and
accumulates in the lower parts of the basin, under the
London clay, immense quantities of water—for it must be re-
marked, that the chalk cannot part with it, except at the points
of its natural overflow, because the underlying clay or marl
upholds the water in the chalk. By sinking a well into the
saturated parts of this vast reservoir, water can be obtained;
and if the perforation be made through the London clay, at or
near the centre of the basin, directly the porous and saturated
strata are arrived at, the water will gush up with great violence.
This situation, therefore, is a most suitable place for an
Artesian well; and the fact is fully known and appreciated
around London, though it is only near the valley of the
Thames where the water rises very near the surface; yet its
rise in other parts is sufficient to be of great practical im-
portance. As the higher portions of the basin are approached,
the rise becomes proportionably less, and the Artesian must
give place to the common well.

In the case of rocks impervious to water, and which are
covered with a porous strata, or matter composed of the
*débris of the older* rock itself, should the rock assume a

depressed or undulated structure, as in Fig. 5, Plate 1, water might be expected to be found in such valleys or depressions; and the depth a well would require to be sunk, would vary according to the undulations of the water-sustaining surface; thus, at *a*, water might soon be arrived at; at *b*, which is nearly on the same surface level, two or three times the depth of the well at *a* would be required; while at *c*, which, according to the surface of the ground is lower than either, a very little water would be found at all, as all that percolated through the porous matter would be conducted by the sloping impermeable rock below, to the valley *d*. Should a well be required in such a section of country as represented by Fig. 3, in which *a* is impervious matter overlying *b*, which is of a porous nature, and which rests on the rocky substratum *c*, a bare inspection of the figure will show that the water collected from the outcrop of the porous substance *b*, to the dotted line, is accessible to wells sunk through the impermeable deposit *a*. But from the dotted line to the valley *d*, the search would be very precarious, as all flowing over the projecting portion of the rock *c*, would at once find its way to *d*. Referring again to Fig. 3, if we suppose the projecting part, or fault, as it may be termed, continued to the surface of the ground, it is evident the water will be entirely dammed up by it, and the only discharge for the water underneath will be by overflows at the outcrop of the saturated porous matter; but if the head of water becomes very great, the probability will be that the water will in places force its way to the surface at the junctions of the fault and the regular strata, forming a fountain, or series of fountains; hence, it has been remarked, that an extended line of such fountains may determine the line of a fault. In any particular district, it becomes a question of great interest and practical importance to ascertain the distance from the surface of the ground to where the water will stand in any proposed well. This fact, which, it must be borne in mind, has nothing whatever to do with the question of where the water may be arrived at, and which depends on the

inclination and dips of the strata, can only be ascertained in
those places where the same springs extend over a great
amount of surface, such, for instance, as the main chalk
springs, and sand springs of the plastic clay formation. In thus
judging from the basin-like structure of the strata, coupled
with the well-known laws of hydrostatics, it might be sup-
posed the levels of all the wells in the district would be the
same; and did no outlet exist but the overflow of the upper
parts of the basins, such would be the case; but though the
lower outlets prevent the water in the wells assuming a
level, yet it is within the range of observation to find the
inclination of the water line. In such formations, the flow
of subterranean drainage will necessarily be to the various
outlets of the water: if the strata dip, the flow of water
is constrained to dip also; and if a well be sunk in this in-
clining subterranean flow of water, the latter will rise into
the well above the perforation of the spring, to a height de-
termined by the head of water itself, and the size and distance
of the outlet close to it. The water would not rise much, if at
all, above the level of the outflow, while at some distance above
the outlet the level of the water might rise in a well many
feet above the same; and further still, though the hydrostatic
pressure of the water might be less, yet still it would rise
some little distance in the well, from the great amount of
throttling action caused by the porous matter interposed between
the well and the outflow; of course not so high as the line of
saturation at the upper part of the basin. Fig. 2, Plate 1,
represents the section of a district draining both ways into the
valley D. Supposing the water supply great, and the outlet
at D contracted, the water levels of various wells sunk in the
district might be represented by the lines at *a a a*, &c.; a
maximum rise above the perforation of the spring taking place
at a certain distance from the outflow, where, however, the
hydrostatic pressure is great. According to the quantity of
water held by the porous matter, so will the levels of the
*water in the wells* rise and fall, and those furthest from the

outlet will be the most affected; at the latter place itself the height will be uniform, or nearly so, until the whole of the water in the spring be exhausted. Though the above figure is drawn solely with reference to explain the subject, yet it applies exactly to the case of the London basin, only that in the latter, in place of one, there are many outflows. That the water incline does exist in that formation is clearly proved by facts. The Rev. J. C. Clutterbuck, of Watford, who has paid great attention to this subject, has recorded his observations: he finds a line drawn from the river Colne, 170 feet above Trinity high water mark, and continued from Watford to the Thames, at an inclination of thirteen feet in a mile, cuts the water level of all the wells in the district, till Kilburn occurs, where a depression takes place, owing, as he supposes, to the pumping around London. North of the Colne, an inclined line rising from Watford 200 feet in fourteen miles, cuts the water level of the wells dug in the chalk, and at the extremity of this line the variation of water level is as much as fifty feet, depending on the quantity of water with which the lower portions of the chalk is saturated; other lines have been remarked, but sufficient has been adduced to establish the general principle, and it appears to the author, from observation of the cause of such inclines of water level, that if careful surface sections were made, these lines, assumed as straight, would appear curves.

Though the London clay has been spoken of as impermeable, yet it must not be supposed that no springs are ever met with in this formation, and that to find water the main spring must always be sunk or bored into, for experience shows that at times springs are met with only a short distance from the surface; and often land springs are found in the sand and gravel which, with the yellow clay, overlies the London or *blue* clay, as it is called, which generally, however, is a brown black. The discovery of one of these springs is sufficiently curious to be remarked: in the premises of No. 2, King Street, St. James's, there are two cellars, one situated *under the* other, and in the year 1837, a hare, which was sent

to the proprietor of the cellar, arriving by some accident in a putrid state, had a burial place determined for it in the lower cellar, when, on digging a hole, not three feet deep, a spring of water was arrived at, which proved of good quality, was at once taken advantage of, and has continued to be used for the supply of the premises ever since. In the case of rocks impervious to water and intersected by fissures, the only hope of finding water is by working for streams in these fissures, an operation similar to that carried on in the wells sunk at Fort Regent, hereafter to be remarked on. The following section, determined by an actually executed well, may give the reader a general knowledge of the upper crust of the London basin; it is compiled from Messrs. Conybeare and Phillips's Geology. More sections are given in a succeeding chapter, but here it is desirable to pass on to other subjects.

Section of Mr. Foster's well at Bromley, near Stratford-le Bow, Middlesex.—Authority, Messrs. Conybeare and Phillips.

| | | | |
|---|---|---|---|
| Alluvian | 18 feet | | loam, clay, gravel, and sand. |
| London clay formation . | 44 | „ | water from beneath it. |
| Plastic clay formation | 2 | „ | blue clay. |
| | 1 | „ | clay, sand, and shells. |
| | 4 | „ | gravel, sand, and shells. |
| | 4 | „ | fine sand. |
| | 9 | „ | blue and yellow clay. |
| | 4 | „ | sand and shells, with lumps of pyrites, and water. |
| | 9 | „ | blue clay, with broken shells and pyrites. |
| | 1 | „ | limestone. |
| | 22 | „ | black sand passing into round pebbles. / black sand, veined. / small pebbles in sand hard and compact. |
| | 2 | „ | blue clay, hard and firm, spring of water, which threw much fine white sand in the pipe. |

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Many apparent anomalies will be found in applying the previous considerations to the case of certain springs ; but generally a little careful examination will reconcile them . thus, for instance, the occurrence of a spring on the highest point of a small island, may at first sight appear an exception. Here, however, the supply will surely be found to emanate from higher districts, it may be many miles off, but which are geologically connected by porous channels of spring water. Intermittent springs, till the theory of them was satisfactorily explained, were apparently irreconcilable with the usual accepted theory.   In these, however, we have only to consider a natural channel embodying the principle of the syphon, as emanating from a cavity into which water is constantly flowing.   Granting the syphon channel to discharge faster than the supplying one, the intermittent apparatus is perfect.  The action is as follows :—On the water flowing into the cavity, it will rise in the discharging channel till it flows over the bend ;  directly it does so, the action of the syphon commences, and will continue till the cavity is so far exhausted of its water as to allow the shorter leg of the syphon to become uncovered ;  the spring will then cease flowing till the syphon discharge again commences.

## CHAPTER III.

### PRACTICE OF WELL-DIGGING.

THE practice of well-sinking may be properly divided into two divisions, digging or excavating being one, and steining or lining with brickwork or stone the other ; in the case of hard chalk or rock, the latter operation is dispensed with, the work being confined solely to excavating,—a lining of brickwork being quite unnecessary for the stability of the work.   Wells are usually of a circular form, and those which are merely picked

in the solid strata, lack the regularity of the nearly perfect
cylinder of brickwork : such wells, however, generally require
steining to some depth from the surface of the ground, owing
to the looseness of the surface soil ; this is exemplified in
many parts of Hertfordshire and elsewhere, where a gravelly
surface soil overlies the chalk. The mere excavation of a well
requires but little skill, though at times it is a matter of
great labour, requiring, in hard rock, blasting the plumb-bob,
and a rod marked with the diameter of the hole, being suf-
ficient to insure accuracy.  Buckets, a windlass, and ropes
are required to remove the products of the excavation.  Plate
4 contains these things in sufficient detail to render any de-
scription unnecessary.   Where the well is sunk through stiff
clay, as, for instance, that in the London basin, steining of
half-brick thick, or four inches and a half, is required for
small wells, and of nine inch work for wells of large diameter.
Great improvements have latterly been made in the method
of carrying on, and also in the stability of this description of
brickwork, owing to the use of Roman and other descriptions
of cement entirely superseding wedges of slate, bond timber,
and common mortar: the two latter are especially injurious,
as the timber will decay and the lime in the mortar, unless it
be blue lias or equally hydraulic lime, will dissolve out into
the water contained in the well, rendering the same very hard;
besides, as will be seen when describing the manner of
steining, the slow setting of the mortar is a bar to its
general use.   Loose wet sand, or loam, try the skill of the
well-diggers ; in such cases, however, it may become necessary
to puddle behind the brickwork, and care must be taken that
the upper steining should not slip while so doing,  Again, in
passing through land springs, they must be carefully walled
out, by executing the brickwork entirely in cement—an opera-
tion which can only be done when the quantity of water en-
tering from the spring is limited; where the rush is enor-
*mous,* as in sinking through the main sand springs of the
*plastic clay formation,* the water must be dammed out, by sub-

stituting for brickwork cylinders of iron, which may be either cast or wrought; the latter are the most modern, and have been applied in some large wells; the former are the most convenient for handling, being bolted together in segments, or in divisions. When the sinking such cylinders is neces-sary, digging will most probably be precluded altogether, and boring alone will be admissible, the cylinders sinking as the sand is bored out: when they have been sunk to a sufficient depth in the solid clay beneath, digging and steining may go on as before. If it be determined to bore, near London, into the chalk, boring should commence before the sand spring be entered, the expense of large cylinders being thereby saved, as their place would be taken by the small bore pipe; and as the water from the chalk will generally rise higher than the level of the sand spring itself, no advantage is gained commensurate with the increased outlay by sinking cylinders. The position of the sand spring can be determined by boring in advance of the well itself, while the latter is being sunk through the plastic clay: by driving a bore hole very small, and thus feel-ing the way, no danger of a surprise may then be anticipated. Steining is executed in a variety of ways, as regards its manner of application, its thickness, and its bond, The bricks used should be hard, square, and well burnt; if the cost will allow, malm paviors should be used, and if stocks, they should be the very best. As the work is for the most part laid dry, unless the bricks run of one uniform thickness, a great waste of time and trouble will unnecessarily take place during the steining: again, as the bricks are laid so as only to touch each other at the edges, a soft crumbling brick would mani-festly be useless. The old method of carrying on the steining was by building on a curb of wood shod with iron. The earth being removed from the bottom, the curb and its superstruc-ture sunk down; the brickwork was then added from the top, and this method of proceeding continued till the curb would sink no longer, owing to the swelling of the ground; a new curb and new excavation smaller than the last was then begun.

well, or alter their position, must force outwards one or other of their two neighbours, G. G., these cannot evidently be so moved without compressing the solid ground behind; here, again, we see the advantage of working as close as possible to such ground, and, if at any time, owing to a stone or otherwise, the excavation be not perfectly round, care should be taken to puddle with solid clay behind the steining to prevent displacement, by thus forming a sufficient abutment.

The work when 9 in. thick is laid either radiating, as in Fig. 3, Plate 5, or in separate 4½ inch rings, Fig. 4; the latter plan is usually adopted, and may be considered the best, for the following reason, it being understood that the work in both cases is laid in cement. Considering the strength as that of a compound of bricks and cement in Fig. 4, fracture of the cement must take place before any failure, while in Fig. 3 a slipping of the bricks away from the cement might arise; and again, in executing the work it might be considered advisable—indeed, it generally is—to execute the back steining first, for a certain distance, and afterwards to complete the inner. Even work, not wavy, but strictly vertical, constitutes good steining, and looking upwards from the bottom of a well will at once detect if the work be true or not, the eye in such case being placed close to the steining. Well-diggers, after attaining a certain depth, find the confined air very unpleasant and noxious. The carbonic acid from the breath, being specifically heavier than common air, soon stagnates at the bottom of the excavation; lime water is sometimes recommended, as this will absorb the carbonic acid; it is, however, a dirty and unworkmanlike expedient. A pair of bellows or a fan blast should be used in such cases, and the air conveyed down the well in pipes; thin zinc ones answer the purpose very well, they are about two inches diameter. The depth of hole at which artificial supply of air is desirable will depend on the diameter of the well, and the position of the aperture. If it be open to the air, with no *temporary shed* or other erection over it, a supply may not be

required, with a four feet excavation, till about 130 feet from the surface. In this question, however, the extreme limits should not be sought for, as the sooner a plentiful supply is given the better, the workmen getting on more comfortably to themselves, and also much faster. A few words must be said on the construction of iron steining or the cylinders before alluded to. The wrought iron ones are riveted with internal ribs of angle or T iron, so as to be flush on the outside, the rivets being countersunk to attain this end; lowering rings are also riveted inside them, for convenience in fixing. Cast-iron cylinders being much thicker, therefore · heavier, will sink into the hole with less driving; they are cast in about five-feet lengths, and are joined together with bolts and internal flanges. In sinking cylinders, their vertical position must be insured by letting them travel or slide between four battens, fixed as guides, and secured to the brickwork. When iron cylinders are used, it is generally necessary to secure up the lower part of the brickwork, as the sand and water will give it no support; an elm or iron curb is therefore used for the purpose, which is secured by iron rods to wood beams let across the well, or iron curbs inserted some distance up the shaft. The space between the cylinders and brickwork should also be well concreted, so as to shut out the water, which would otherwise rise up from the sand. To prevent land springs or drains from percolating into a well, it is well to execute the first ten or twelve feet from the surface, in nine-inch work, the same being well puddled behind. When the surface soil itself is close upon the stiff clay, this may be neglected; and, when the land springs are very strong, they must be shut out by the use of cylinders as previously described.

## CHAPTER IV.

### BORING.

THOUGH boring practically requires skill and care, yet in principle it is extremely simple. The operation consists, as its name would imply, in working a hole, in this case made in the crust of the earth, of a diameter varying according to circumstances, and in a vertical direction generally; not · always, however, so, for certain requirements may demand that it should be oblique. Many systems have been and now are practised in carrying on this kind of work, and though in England but one is usually followed, of many modifications it is true, yet it would be well to mèntion one or two other plans. The simplest is that practised in various parts of the continent, and called the Chinese system; here all rods connected to the boring tool in the ordinary plan are dispensed with, the borer being suspended by a rope, which, when the tool is worked vertically up and down, imparts by its torsion a sufficient circular motion in the tool. This plan is represented in Plate 6, Fig. 1, where *a* represents the tool, which is surrounded by an iron cylinder. The products of the excavation become collected in the circular space between the tool and the cylinder, by which means they may be brought up to the surface of the ground. With so simple a machine, different tools, of course, being used for various strata, it may be asked why has this plan not superseded all others? Now, where simplicity can be gained without corresponding disadvantage, it is well to employ it; but where a manifest inferiority exists, to choose simplicity in opposition to complexity, for its own sake alone, is absurd. To this plan one serious drawback occurs, which is, the bore hole is apt to become crooked, so that a great difficulty, if not impossibility, would take place in sinking the pipes necessary *for protecting the* hole. That this fault could be rectified

there can be little doubt; but, till such is done, the system of boring by impact alone, assisted by the twisting action of the rope, will never become very general.    In rocky strata, or in places where the straightness of the hole is of little moment, this method may do very well.    The ordinary plan is to attach the borer, which differs according to the nature of the work to be done, to iron rods, which screw together in lengths of from ten to twenty feet; a circular motion being given to the borer by the workmen above, assisted when required by a vertical jumping motion, causes the boring tool to work for itself a hole in the ground.    It is evident, by this plan, a great loss of time is entailed, for the tool, when it becomes full of the products of the boring, must be drawn up to the boring stage, to be emptied of its contents, to effect which the rods must be unscrewed.    This unscrewing and screwing, pulling up and letting down, is an operation which, if it could be done away with, would be very advantageous. An apparatus has been proposed and patented to accomplish this object; it was patented by Beart in the year 1844.    The rod connecting the boring tool with the workmen above is hollow, forming a tube with water-tight joints ; into this tube water is allowed to flow, an upward and downward current of the same being gained by allowing the water to flow in one direction in the tube, and in the other in the circular space around it.    The strength of this current the inventor considers sufficient to carry up with it the materials which are loosened by the boring tool.    That some loose matter could be so carried is probable, though in a majority of cases it is likely it might be impossible.    Another objection to this arrangement is the immense quantity of water necessary, an article which, in sinking a well, is not usually very plentiful, till obtained from the well itself.    Confining ourselves, therefore, to the ordinary system, it will be well, in the first place, to notice a few preparations which are necessary before commencing the boring itself.    Assuming a well sunk so deep that we are certain that when the spring is tapped the water

will rise a sufficient distance in the well, the first con-
sideration will be, can the boring take place from some point
in the well itself, or must we work from the surface? The
answer to this will depend on the depth of the proposed bore,
together with its diameter, and the nature of the ground to be
worked into. If the well be under four feet diameter, it is
hard to obtain sufficient leverage for any heavy work, if the
boring takes place from a point in the well distant from the
surface of the ground; in that case we are driven to work
from the surface, but, where it is possible to bore from below,
it is better to do so, for the following reasons, among others :
first, there will be a great saving of temporary work above
ground, for the stage the workmen bore from must, if above
ground, be elevated some distance from the surface—twenty
feet at least — or great waste of time will take place in
screwing and unscrewing the rods, &c.; secondly, a less
weight of rods will be on the windlass, for, if the boring takes
place from a point in the well, the rods need only to be sus-
pended by ropes from the windlass to the stage in the well
from which the boring takes place ; and there will be an
economising of time in screwing and unscrewing the rods, as
they may be drawn up without detaching them from each
other in lengths equal to the distance of the windlass to the
boring stage nearly.    To reap the same advantage when
boring from the surface, a high pair of shears or a triangle are
requisite for the purpose, which, of course, is an additional
expense and trouble.

Supposing it decided that boring should be carried on in the
well, care should be taken to fix on the position of the stage
or floor from which the work is done; this should be as low
as practicable, as may be supposed from what has been said
before; but at the same time the stage should be a sufficient
distance above the level in the well to which the water will
rise.    This is a consideration which can be arrived at only by
experience, and a knowledge of the spring water level of the
*district.    The stage* consists of a stout plank floor, resting on

strong putlocks. The flooring is well braced together, by planks nailed transversely across the same. In the centre of this floor is a square hole, a little larger than the boring rods, which therefore can pass through it, but not large enough to allow a small hook apparatus, to be hereafter described, which, having the power of holding the rods suspended while they are screwed and unscrewed, thus prevents them falling through the stage. From the bottom of the well to above where the water will rise, say to nearly under the boring stage, wooden trunks, strongly but temporarily secured, are fixed as guides for the boring tools, permanent pipes, &c., &c. These trunks may be made square, and are fitted by sockets one into the other. Sometimes temporary iron pipes are used, instead of these wooden trunks. The permanent pipe to be inserted in the hole bored should be joined together and slung down the well, ready to be fixed when occasion may require. Thus having, we will suppose, bored through the mottled clay, the sooner the pipes follow the better, as the sand underneath is liable to blow up into the bore hole, or the clay itself, when not dense and stiff, may fall, and to a certain extent choke up the hole. These pipes are either of cast or wrought iron; the latter are generally used for small distances, and the former, as being thicker, for very deep work, where much driving will be required. The lower pipes of the series are usually perforated with small holes when the spring is a sand one ; but, when the water is to rise from chalk or rock, no perforation is required, as the pipes themselves are only requisite, as far as the bore hole will not stand without them. In many cases in and about London, advantage is taken both of the main sand spring and the chalk springs also ; then perforated pipes are well driven in the former, smaller pipes and a smaller bore being continued to the chalk. A length of wrought and cast-iron pipe is shown in Plate 6, Figs. 2, 3, and 4. The junctions of the pipes show nearly, sometimes quite, an even face on the outside. The cast-iron ones have generally turned joints, and wrought iron collars, usually flush

inside as well as outside; if, however, required to be slighter, they may be cast as shown in the figure, for, if the thickness at the joint is the same in both cases, no advantage, as far as passing tools up and down, is gained by having the internal diameter uniform throughout, though there is a great advantage in point of strength. The collars are sometimes fixed on the pipes with screws; though, when the joints are not turned, they are run together with metal: this latter plan will entirely shut out any bad water, should any be met with; but the other is the favourite one. The wrought-iron pipes are now seldom riveted, but have thin collars soldered on to the pipes; these are never quite flush outside. The melting of the solder which is previously run in the parts, is accomplished by suspending an iron heater down the pipe. The hook and heater are represented in Plate 6, Figs. 5 and 6, the small heater being made of one, and the larger heater of two circular pieces of iron. The pipes are slung down the well, by means of a wooden plug, Fig. 7, Plate 6, which plug has a pin, or key, passing through it. This, inserted into the end of the pipe, which is cut reversely, as shown in Fig. 8, will clearly hold up the same, and, merely turning round the plug after slacking it, the pipes will become detached; by this plug, also, the pipes can be driven.

This small groove, though very simple, is extremely useful, as being capable of action at any depth, and where it is completely out of sight of the workmen. The boring rods are usually turned round by the leverage of two handles, shown in Figs. 9 and 10, Plate 6; where the work is too heavy for these levers, an increase of manual, or even horse power, can be applied. Besides the circular motion of the tool, a vertical percussive action of the same is required in certain cases, such as rock, or hard sand; indeed always, where the position of the auger or chisel requires a fresh place to act upon during its revolution. This motion is most readily got by suspending the boring rods to the windlass, through the intervention of a *rope, coiled two or three* times round the latter, and adjusting

it so that if a workman holds one end of the coil tight, sufficient will be the friction to raise the rods on putting the windlass in motion. Should the end of the rope the workman holds now be slacked, the coil becomes loose, and the rods descend with a force equivalent to their weight, and the distance through which they have fallen. A regular percussive action is therefore gained, by keeping the windlass continually in motion in one direction, the attending workman alternately allowing the rods to be drawn up a certain distance, and then, by relaxing his hold, allowing them to fall. The connection of the rods is shown in Fig. 11, Plate 6. They are made in lengths of from ten to twenty feet. The projection seen in the middle, together with the same at the end of the rod, are useful for suspending them by the hook, or dogs, as they are called, referred to before, and which is shown in Plate 7, Figs. 6, 7, and 8. The latch *a*, which opens on *b*, as a hinge, allows the projecting knob of the rods to enter, and when shut secures the same in its clutches; the dogs can be suspended themselves by a rope, or they may be supported on the boring stage in the manner before spoken of. Fig. 11, in the plate, shows the male and female screws by which the rods are united together. Some of the tools used in boring are represented in Plate 7, and the two following ones. Figs. 1, 2, and 3, Plate 8, show an elevation, plan, and section, of an auger. The tapped socket is for the purpose of allowing the rods to be screwed into it. The leading nose *a*, is for cutting, and the valve *b*, is to prevent the material cut from falling out of the auger, while the same is raised to the stage. Figs. 4, 5, and 6 show a similar auger, but of a larger size; this has not a screw tapped into a socket as the former one, but instead is bolted to an intermediate rod. Figs. 7 and 8 are two views of a small auger, with a longitudinal slit, and no valve; used chiefly for boring through clay and loam. In very stiff clay, the slit may be a very wide one; in soft clay, narrower; while, in very moist ground, it is inadmissible altogether. Figs. 9, 10, and 11 show an S chisel for cutting

c 3

through rocks, flints, &c. This tool is worked with a vertical motion, got in the way before described, as well as in a circular direction. Figs. 1, 2, and 3, Plate 7, represent a large shell; *a a,* are two valves, opening upwards to admit the material; this tool is used in boring through sand, or hard ground, after the same has been loosened by other tools. Figs. 4 and 5 show a small shell, similar in principle, but slightly differing in the detail, there being but one valve, and the edges of the shell cut square, instead of slanting. Both these tools are worked with the compound of circular and vertical motion. Figs. 1 and 2, Plate 9, exhibit a spring rymer; the cutting edges are placed reversely, and the size is regulated by means of the screw and swivel, *a b.* This is an essential tool for enlarging a hole. When the pipes are inserted some distance, it is important that under them the bore should be so far widened as to allow the pipes to be driven further; and this tool can be forced down the pipe in a partly collapsed state, springing to its set dimension as the softer ground under the pipe is cut away. Figs. 3, 4, 5, 6 show a spring latch tool for raising broken rods; the forked hinge *b* has a tendency to shut, by the action of the spring *a;* therefore, when the tool is forced over the knob of the broken rod, as represented in Fig. 6, the spring shuts the forked hinge under the knob, by which, of course, the broken knob can be raised. Fig. 7 is a spiral instrument, something like a cork-screw; this is used for the same purpose when the knob on the rod cannot easily be got hold of, or when the weight to be raised will not overcome the friction of the screw. A tool fashioned like a common lifting pump is often used for very soft mud,—a vertical up and down motion filling the body of the tool with the soft matter. Another useful boring tool for hard substances may be described as a spiral winding round a hollow cone; as boring goes on, the material accumulates in this cone, and may be thus raised to the working stage. It must not be *supposed that the* foregoing description includes every tool

used by borers, or that all contractors use the same. Different opinions exist as to the detail of the various augers, and many tools used during boring depending on very peculiar circumstances, or common to other descriptions of work, need not here be described. In certain cases guides are required, to ensure the vertical direction of some of the above tools; these are most readily obtained by bolting, either to the tools or rods, four wrought iron bars bent at the ends, so as to exactly fit the hole between the extremities.

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## CHAPTER V.

### VARIOUS METHODS OF RAISING WATER.

As it is desirable to make this paper as practical as possible, that space which might be taken up in describing methods of raising water in ancient times, or those proposed in our own, which practically have not superseded the pump, or common windlass and bucket, shall be passed over. All elementary books on hydrostatics and hydraulics contain descriptions of Archimedian screws, endless bands, Jacob's ladders, Persian wheels, &c., &c. ; to such works the reader must therefore be referred. The common bucket and windlass is the simplest arrangement for raising water from wells, and, in parts of the country where wells are deep, is used in preference to pumps, except where a large quantity of water is required; for, as will be presently shown, the common pump will not draw water more than thirty or thirty-three feet at most, some- times, taking imperfections into account, not more than twenty-five, while the deep well pump, from its situation, rods, rising main, &c., is a more expensive affair than the bucket and windlass. In some districts the springs are within a few feet of the surface ; here a pole with a hook at the end, to which the bucket is attached, supplies the place of the rope and windlass. Where a windlass is used, it can be

worked either by hand or by horse or donkey power, the horse-wheel working either horizontally, as in the case of a pug or clay mill, or vertically, the animal working from inside the wheel or drum. Often the windlass, though worked by hand, is on a second motion, a spur wheel situated on it, gearing into a pinion fixed on the axle, to which the winch is attached. When this arrangement occurs in a roofed shed, the sides being opened, and roof supported by framed timbers, the effect of the whole is very picturesque. Examples of the above methods of raising water are very common in parts of Hertfordshire; they answer very well for small quantities of water periodically required, but for filling cisterns or reservoirs, &c. are of very little use, and for such purposes pumps are always adopted.

The principle of the pump is very simple; in its most common form the pump consists of a barrel truly cylindrical, into which fits the sliding portion of the pump, or bucket, as it is called : see Figs. 9, 10, Plate 10, which represent sections of the same pump. The bucket *c* has a valve in it opening upwards ; a similar valve, also opening upwards, is situated at the bottom of the barrel ; this is called the sucker, and is marked *d*. The action of the pump is as follows : when the bucket is drawn up in the barrel, into which it fits air-tight, a partial vacuum will be formed under it, more or less perfect according to the perfection of the apparatus ; the valve in the bucket will be kept shut by the pressure of the air above it, while the valve in the sucker will be forced upwards by the water rising into the barrel—see Fig. 9—which water is forced into the vacuum under the bucket by the air which presses on its surface in the well; in other words, by abstracting the pressure of the air from off part of the surface of the water, the portion under it is forced upwards by the pressure on the remaining portion of its surface, just as, in compressing a bladder full of any liquid, the latter will gush out at any aperture, there being little or [no resistance at that *point*. Supposing the up stroke of the bucket complete, and

the space under it charged with water, on commencing the down stroke—see Fig. 10—the water cannot return downwards through the sucker $d$, for the valve in it will be shut by the pressure of the water, but the valve in the bucket will rise by the same pressure; thus the position of the water will be changed from under to over the bucket. It is manifest that, on the up stroke of the bucket, the water resting above it can be raised to any height required; but, as before stated, the distance is limited by nature as to the height from the level of the water in the well to the body of the pump itself. The reason is as follows: the pressure of the air on the surface of the water balances a column of water in the suction pipe; it follows that, if the height of the pipe is such that the column of water equals in weight that of a column of air of the same diameter, and of the total height of the atmosphere, the column of water would be pressed upwards no longer, for the two weights would be in equilibrium. That the comparison should be made with a column of air of the diameter of the pump, and not the total weight of the air pressing on the whole surface of the water in the well, will be understood by imagining for a moment the effect of having a pipe one square inch in area, and of length sufficient to contain a quantity of water greater in weight than that of a column of air also one square inch in area, and of the total height of the atmosphere; on filling this with water, the lower end open and immersed in the well, the effect would be that the pressure on the square inch under the pipe would be greater than the pressure per square inch of the air on any other part of the surface of the water in the well. The particles of the water, from their extreme mobility, would transmit this pressure in all directions; the extra pressure per square inch being divided equally throughout the mass, would react against the total atmospheric pressure, causing the latter to yield; the general level of the water, rising from the additional quantity running in, and which will continue till there is an equilibrium of pressure per square inch between the

water in the pipe, pressing on the surface of the water in the
well, and the pressure of the atmosphere.   Comparing the
relative weights of water and air would give a much greater
distance between the water level and the sucker than practice
would authorise us to adopt; where circumstances will allow
of it, the suction should not exceed twenty-five feet.   When
a great quantity of water is required continuously, and the
spring supply is not equal in a given time to the throw of the
pumps, the latter must be fixed close, or even under the sur-
face of the water, thus insuring at starting a good reservoir of
water under the pumps.   The accompanying table contains
the number of gallons for every foot in depth in wells of
different diameters.

| Diameter. | | | | | | Contents in galls. |
|---|---|---|---|---|---|---|
| 2 | 0 | . | . | . | . | 19¾ |
| 2 | 6 | . | . | . | . | 30½ |
| 3 | 0 | . | . | . | . | 44 |
| 3 | 6 | . | . | . | . | 60 |
| 4 | 0 | . | . | . | . | 78 |
| 4 | 6 | . | . | . | . | 100 |
| 5 | 0 | . | . | . | . | 122 |
| 6 | 0 | . | . | . | . | 176 |
| 7 | 0 | . | | . | . | 239 |
| 8 | 0 | . | . | . | . | 313 |
| 9 | 0 | . | . | . | . | 396 |
| 10 | 0 | . | . | . | . | 489 |

The details of an ordinary pump are shown in Plate 10;
they were obtained through the kindness of Mr. Fowler, of
Dorset Street, pump manufacturer.     Figs. 1, 2 are the
elevations of the bucket, which is composed entirely of brass;
the screw at the bottom is to allow for the fixing of the
leather packing shown in Fig. 4.   By means of the ring seen
in Fig. 3, these cup leather packings can be always removed
or refixed by screwing or unscrewing the ring, Fig. 3.   Figs.
7, 8 are an elevation and section of the lower clack or valve,

usually called the sucker; the grooves are for packing of hemp, and, when driven into the conical part of the body of the pump, the junction is air-tight. To remove the sucker, a hook is inserted into the pump barrel, so as to lay hold of the part of the sucker *b*, by which it can be raised. The clacks themselves are of leather, with a brass plate screwed to the upper side, shown in Figs. 6 and 8; they are both alike, and are fixed to their seats by a brass strip screwed to the seats. Fig. 5 shows the bucket clack seat. Fig. 6 the clack, *a* being the brass plate, and *c* the slip above referred to. Fig. 8 shows the sucker clack in section, the same letters refer to the same parts of the clack as in Fig. 6; it will be noticed that the hinge is formed by the elasticity of the leather itself. The body of the pump can be imagined from the sectional sketches, Figs. 9, 10; it is either of lead or cast iron, usually the latter when the bucket and sucker is of brass, as with lead, wood is generally employed for those parts. The deep well pump, shown in Plates 11, 12, differs from the one above described in having the sucker or lower clack fixed between the flanch of the barrel and tail-piece of the pump, and also another upper valve inserted between the flanch of the pump barrel and rising main. In Plate 11, *a* and *b* represent the positions of these clacks; the bucket is similar to the one described; the upper clack is not needful for the working of the pump, but is useful in a variety of ways.

A description of pump for mining and deep well work, and called the plunger pump, remains to be described. Here the bucket is dispensed with, and in its place a solid cylindric plunger slides air-tight through a stuffing box. The up-stroke of the plunger will cause a partial vacuum in the pump barrel, water will therefore rise into it through the lower clack. The [barrel of the pump communicates with another and similar clack opening upwards; the down-stroke of the plunger will therefore force the water from the barrel of the pump through this valve, which, of course, by shutting, prevents the water returning to the pump. In addition to

many reasons hereafter to be mentioned for employing this pump in certain situations, the little trouble in attending to the packing causes it to be a great favourite with workmen, who prefer attending to the plunger packing instead of removing the buckets for putting on fresh leather. It is obvious that this description of pump can never be slung under water as the lifting pump can, therefore the latter is used for the lower lift when the pumps are arranged in an ascending series.

. More pumps are usually used in well work than one, except in very small work, where the motive power is manual, acting on an ordinary pump handle ; where that or any other force acts through the medium of wheel work, the irregularity of motion caused by the varying resistance of the pump is so great as to require the work to be done divided, either by placing a counterweight so as to render the up and down stroke of the pump uniform in resistance, or to fix more than one pump. Perfect regularity of resistance takes place when three pumps are used, worked by an axle having three cranks, set at an angle of 120° with each other. When the power applied to them is uniform, and not governed by a fly wheel, this arrangement is worthy of adoption. The objection to having three pumps is on account of its expensiveness and complication, together with the increased friction of three sets of pump buckets and rods, so that, whenever a fly-wheel is used, it will be better to use two pumps than three, as nearly perfect regularity of motion can be insured, and a less complicated arrangement gained. The above remarks, it must be remembered, only apply to pumps worked through the intervention of wheel work.

In the case of large pumping engines, which act directly on the pumps themselves, all the features of the subject are altered. It sometimes is desirable, in very deep wells, to raise the water in separate lifts, that is, the pumps are situated at various heights up the shaft; the lowermost one *supplies a cistern* from which the pump directly above it

draws, and this, in like manner, feeds the pump situated in the next lift. The advantage of this arrangement is obvious. Each pump has a comparatively small weight of water to raise ; a lesser strain is thereby occasioned, and, in case of any leakage of the clacks or buckets, the same is not so disadvantageously felt. The material of which pumps are made differs, they being either of wood, lead, iron, brass or gunmetal. Wooden pumps are now nearly out of date; leaden pumps, with wooden buckets and suckers, are extensively used for shallow wells, raising water from ponds, reservoirs, &c. ; iron pumps are also used for the same purpose, and also for fixing in deep wells; they are inferior to brass or gunmetal, as being more liable to corrosion, but they are cheaper, and experience has shown them not to corrode so rapidly as might be supposed ; indeed, it is not so much in the barrels of the pumps that corrosion takes place (water alone having no oxidating power) as in the rods, nuts, screws, and other parts exposed to the joint action of air and water. Pump rods are either of copper or iron ; copper is the best, but the dearest; the iron ones corroding very fast, especially where they pass through the guides ; the junction of the rods are scarfed and secured by brass or iron ferrules : this is shown in section in Fig. 2, Plate 11. The rods can be thus readily taken asunder by merely loosening the ferrules by driving them with a hammer upwards. The guides for keeping the rods strictly vertical are either made of wooden cleets, seen in Fig. 3, same plate, or of brass rollers bolted to cross timbers, Fig. 4 ; the former plan is the simplest, and by many considered as the best, and as usually fixed; no doubt it is so, for, the guides being inexpensive, more are fixed than when rollers are used. Formerly the distance between these guides exceeded the present practice ; experience has shown that a distance of six feet is not too close where the works are not on a large scale. In computing the quantity of water a pump will throw at a given velocity, and the power required to work it, the following memoranda will be found useful :—

WEIGHT OF WATER, ETC.

| | | | | |
|---|---|---|---|---|
| 1 cubic foot | . | . | . | . 62.5  lbs. |
| 1 cubic foot | . | . | . | . 6.25 gallons nearly |
| 1 gallon | . | . | . | . 10.0 lbs. about |
| 1.8 cubic feet | . | . | . | 1 cwt. |
| 35.84 cubic feet | . | . | . | 1 ton |
| 11. 2 gallons | . | . | . | 1 cwt. |
| 224. 0 gallons | . | . | . | 1 ton |
| 277.274 cubic inches | . | . | . | 1 gallon. |

The quantity of water thrown by a pump will equal the cubic contents of the space in the pump barrel comprised in one stroke of the bucket, multiplied by the number in any given time; this is evident, as in one stroke a quantity is discharged equal in diameter to the barrel, and in length equal to the play of the bucket. Thus, suppose a pump 3 inches diameter, 9 inch stroke of bucket, working 27 strokes per minute, required the quantity of water delivered. To find the contents of the pump we have to square the diameter × by .7854 and then by the length of stroke, 3 sq. = 9 × .7854 = 7.0686 for the area (so as to occupy less space, neglect the decimals); 7 multiplied by 9 the length of stroke = 63 cubic inches, for the capacity of one stroke 63 × 27 = 1701 cubic inches, or very nearly a cubic foot, which is 1728 cubic inches, that is, very nearly $6\frac{1}{4}$ galls. The above calculation, when applied to large pumps, has all the terms in feet instead of inches. In ascertaining the power necessary for working the same, it must be borne in mind that the resistance opposed to motion is the friction of the bucket and other moving parts, the weight of the rods unless they are counterbalanced, and the weight of the water moved. The weight of the latter, whatever be the diameter of the pipes to or from the pump, is equal to that of a cylindric column, the diameter of the pump barrel, and in height equal to the distance from the surface of the water in the well to that of *the reservoir* into which it is delivered; in other words, the

total height raised. The friction of the working parts depends on various circumstances, and the friction of the water on the material and size of the rising main, section pipes, &c. &c.; one-fifth the total weight of water is usually allowed for friction, and though it is manifestly absurd to so make it a fraction of the weight of the water, when it really depends on other matters, yet the above fraction is useful to remember, as generally providing sufficient power.

The above applies only to the resistance to motion; that, together with the speed at which the work is done, really is the test of the power required; multiplying, therefore, the total resistance by the speed per foot per minute that the pump bucket raises the water, the result will be an amount by which to compare the relative power of the prime mover, whose dead pressure multiplied into its speed per foot per minute must exceed that of the work done. Commercially it is allowed that a dead weight of 33,000 lbs., moving over one foot per minute, shall equal a horse power; a comparison is therefore at once set up by which to measure the work, and also to provide the power. The above shall now be applied to the preceding example: suppose the total height the water is to be raised is 99 feet. The following consideration will be useful, viz. on squaring the diameter of a pipe in inches, the product will be the number of pounds of water avoirdupois contained in every yard of pipe.

In 99 feet are 33 yards, which, multiplied by 3 squared, or $9 = 297$ lbs. The bucket makes 27 strokes per minute, moving the column of water each stroke $9''$, in all $27 \times 9'' = 243$ inches, or 20 ft. $3''$ in. per minute, multiplying the resistance, 297 lbs. $\times$ 20 speed in feet per min., we have $=$ to 5940 lbs., moved over one foot per minute. Add for friction, say 1000 lbs., and 6940, equal the momentum of the prime mover, or rather more than one-fifth of a horse power.

Should it be required to know, can a man, acting on a winch connected by wheel work with the pump, work it? The com-

parison is easily made.    Imagine the revolutions 50 per
minute, made by the winch ; the distance travelled by it in
one revolution four feet ; the man's force continually acting
throughout the revolution to be a pressure equal to 40 lbs.,
we have forty, force, multiplied by four, distance of one
revolution, equal to 160 multiplied by 50, number of
revolutions, equal to 8000 lbs., moving over one foot per
minute, an amount quite sufficient to work the pump.    The
size of the pumps and number of them being determined, the
prime mover is the next question.    In all cases where a con-
tinuous supply of water is required, or where large cisterns
are to be filled, manual labour, even for small pumps, will
be found the worst and dearest.    Water power is seldom, for
obvious reasons, applicable.    Wind can sometimes be applied,
and, where it can be depended on, will supersede all others ;
but it is only in peculiar situations where it can be trusted.
The above motive powers, however, all give place to steam,
which, under all circumstances, can be used.    On a large
scale, the use of steam is sufficiently extensive ; but its advan-
tages in superseding manual labour in filling cisterns, &c.
have not hitherto been sufficiently appreciated.    The work
can be done much quicker, and it is nearly self-evident that,
even with such a small-sized pump as the one alluded to in
the foregoing examples, a man's time is better applied in
tending a small engine for three or four hours than in slaving
like a machine for double or treble the time.    It is clear he
must rest, while the engine never tires ; and equally so, that
he who tends the engine is, after pumping, an intelligent
servant, fit for other work, while he who acts machine him-
self is, by the very nature of the work, unfitted for any
higher occupation.

When pumps are applied to an existing horse wheel—I say
existing, for few now choose horse power before steam, unless
the wheel is already erected—the number of revolutions of
the wheel should, by a train of toothed wheels, be so propor-
*tioned as to work the* pumps at the speed best suited to them.

This velocity depends greatly on the size of the suction and delivery pipes; the larger the pipes, the quicker may be the motion. The size of the pumps, and the height of the lifts, must be taken into account. When pumps work too quickly, they are apt to jerk, and are sure to strike their clacks, with great force, into their seats. When too slow, the motion of the pump becomes quivering. The following examples will illustrate the subject :—

| Situation. | Size of pump. | No. of effective strokes. |
|---|---|---|
| Hampstead water works | 2′.3″ stroke . 9″ diam. | 15 |
| Kilburn brewery | 9 ,, . . 3 ,, | 18 |
| Camden station | 2.0 ,, . . 8 inches | 20 |
| Kingsbury | 8 ,, . . 3 diam. | 24 |

When steam is applied to pumping, if the machine be large enough, the steam should be applied directly on to the pump, or through the intervention of a beam alone; this arrangement is the ordinary pumping engine, and is used both with forcing and lifting pumps. The motion of the engine is single acting, that is to say, the steam only acts on the piston during its down stroke, the weight of the pump, rods, &c., acting on the opposite end of the beam completing its up stroke. The single acting engine has one disadvantage when working a single lifting pump, situated in a deep well; that is, a certain amount of power is consumed in raising the pump rods; this can be obviated in more ways than one, generally as follows : the work being divided, say into two lifts, for the lower a lifting pump is used, and for the upper, a forcing, or plunger pump, similar in principle to the feed pump of a steam boiler, and before alluded to. The acting stroke of the plunger being the down stroke, the power required in previously lifting the pump rods is not lost, inasmuch as in their down stroke the power is returned to the work. The up and down stroke of the piston may be thus represented, omitting friction :—the down stroke of piston raises total pump rods and weight of water on lower lift, and on upper lift as far as the

plunger pump sucker; the down stroke of pump rods raises
the piston, and forces the water from the plunger pump
to the top of the lift; thus, in effect, the only work done, if
the lifts be so arranged, is the raising of the water, and an
amount of counterbalance sufficient for raising the steam
piston.    When plunger pumps are used, wrought-iron rods
are dispensed with, the rods being in a state of compression,
and if of wrought iron, unless inconveniently large, would
spring and buckle; wooden rods, or poles, are therefore
adopted.    Cast-iron ones have been tried, but not with the
same success as wood, taking into consideration the relative
strength, lightness, and durability of the two materials.    When
small pumps are worked by steam, the plan of engine above
alluded to, and which is the real pumping engine, is seldom
used, both on account of complication, first cost, and wear and
tear; a steam engine of the ordinary construction, working the
pumps at a less velocity than the steam piston, is found to
answer the purpose better, though an increased expenditure
of fuel is attendant on the choice.    Sometimes the speed is
brought down by intervening wheel work, as illustrated by the
engine at the Hampstead water works, Hampstead Heath, and
also the engine at the well at Kingsbury, shown in the plates.
At other times the speed of the pumps is reduced from that
of the steam piston, by giving the latter a longer stroke than
the pump buckets or plungers have.    An example of this is
shown by the works at Camden station, alluded to further on;
presuming a well complete as regards its digging, steining,
boring, fixing of pumps, engine, &c.    The care of the works
is a matter of more importance than owners usually think.
Periodical visits should be paid to the pumps, for the purpose of
ascertaining their condition, and keeping in order the clacks,
buckets, stuffing boxes, and various moving parts, greasing such
as require lubrication, &c., &c.    A permanent windlass should
always be fixed, or iron ladders, to give access to the well.
An apparatus for blowing fresh air down the well, if it is at all
*deep, should be* provided; and the simplest machine for this

purpose is a kind of wooden air pump, consisting of a vertical square box, open at the top, and at the bottom connected to pipes leading down the well. In this box, loosely fitting, slides a piston, or pump bucket, made of a piece of flat wood, with one or more holes, covered on the under side by a leather flap, or valve, which opens a little way downwards. During the up stroke of this bucket, the air merely changes its position from the top to the under side of the bucket; during the down stroke the valve or flap closes; the air, therefore, will be forced down the pipe leading to the well. In addition to these, some method should be adopted for ascertaining the water level, which varies, generally, by the pumping; a float on the water, attached to a wire, which, in its turn, is secured to a string passing round a pulley, will suffice for this purpose. A pressure gauge, such as that used for a steam boiler, is the most beautiful arrangement for this end, though more expensive. Advantage is taken of it by leading a pipe from the gauge down to the bottom of the water in the well. If this pipe be filled with air, by means of a small pump, the air will necessarily be compressed more or less, according to the height of water above the aperture of the pipe. This compressed air, reacting on the mercury in the gauge, will correctly measure the depth of water. Were it not for leakage, and the absorption of the air by the water, the pump would not be necessary, the pipe alone being requisite.

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## CHAPTER VI.

### NOTES OF WELL WORK ALREADY EXECUTED.

BEFORE proceeding to remark on examples of wells and well-work, already done, it will be better to lay before the reader the following specifications, one of which was used by the author, for a well alone, and the other for one compounded of well-digging and boring.

Conditions and particulars to be observed by the contractor during the sinking, steining, and boring a well, situate at ———, for ———, and to be executed under the superintendence of Mr. J. Swindell, architect, of No. 3, Kilburn Priory.

The work to be carried steadily forward from the commence ment to the completion of the same, a sufficient gang or gangs of men being always employed during the usual working hours.

No deviations to be made in any manner from the covenants and agreements in this specification, and, in case any work should not be to the satisfaction of the above-named J. G. Swindell, the same to be immediately altered and amended.

The care of the works rests with the contractor alone, the owner not being accountable for anything stolen, or for any loss or damage; and in case any unforeseen circumstance should take place, or any accident, of whatever kind, should arise, causing additional trouble,—workmanship, or making good such work, is included in the contractor's accountability, and is to be rectified or made good by him without any extra or additional charge beyond the amount of the contract.

The contractor is to provide all labour, tools, tackle, buckets, windlass, ropes, boring augers, and all and every tool or requisite for carrying on the works ; the bricks, sand, cement, and pipes for lining the bore hole, being alone found by the employer.

In case the contractor shall delay the work or refuse to proceed with the same, the employer, after having given the contracter one week's notice in writing, is at liberty to take possession of all materials or tackle that are on the ground belonging to the contractor, and which he, the said contractor, forfeits by delay or refusal. The employer shall also be at liberty to engage other workman or workmen, and to deduct all the cost and charges thereof, from money due for previous work done by the contractor, the said contractor forfeiting by *his delay or refusal* all such money.

The amount of the contract money to be paid by weekly instalments, calculated to reserve one-half of the cost of the works done, and subject to a certificate from the architect that they are going on to his satisfaction, and are sufficiently advanced to warrant such payments. The balance of the amount due to the contractor on the completion of the work to be paid within one week after the fixing of the permanent pumps.

*Digging and Steining.*—To excavate a well 4 feet diameter in the clear, when the steining is finished, and of a depth of 200 feet, place the earth removed conveniently for wheeling away, the wheeling being performed by the employer. Stein in 4½-inch brickwork the said well, the bricks to be laid dry, with, at intervals, three courses set in cement, such intervals to be regulated by the nature of the clay, but in no case to exceed 5 feet apart; shut out all land springs by bricking entirely in cement and puddling behind the same. Ten feet from the surface of the ground the steining to be 9-inch work, laid in cement, so as to block out surface drainage. Pump or bale out any accumulated water that may occur during the progress of the work. Fill up all putlog holes, and leave the steining in a perfect state.

*Boring.*—At the bottom of the said well, when it has attained the depth of 200 feet, insert, full 2 feet into the bottom, a cast-iron pipe, 12 inches diameter, and 9 feet long; then bore with an 11½ inch auger, shell, or other tool requisite, and fit into the hole 8-inch wrought-iron boring pipes of the usual construction; after attaining a depth of bore at which the 8-inch pipes will no longer drive, insert 6-inch; make all joints in the said pipes secure and good, providing the solder and materials for the purpose. The lower pipes to be well driven into the spring, and to have holes in the same to allow sufficient water way, the upper pipe to stand 12 feet above the bottom of the shaft. Provide and fix all temporary wooden trunks before

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commencing boring, and do all temporary work required during the progress of the boring and other work.

*Contract.*—I, ———, of ———, do hereby engage and agree with ———, of ———, for and in consideration of the sums undermentioned, to do all the labour, finding all tools and tackle necessary in digging, steining, and boring a well, to be done in strict and literal accordance with the covenants and directions of the foregoing specification. The same to be done in the most workmanlike manner and to the entire satisfaction of Mr. J. G. Swindell, architect. The contract money to be as follows, viz. :—For executing completely the 200 feet of well work           ; for the first 100 feet of boring at the rate of           ; the next 20 feet an increase of       per foot, and increasing per foot every 20 feet deep the sum of   .   I hereby undertake to go on with the work till ordered in writing to stop by my employer, and to satisfactorily complete the work, without any extra charge beyond the said money mentioned above, which is to be calculated only to the depth of the work actually done.

N.B.—The reason no prices are given in the above is because so doing might greatly mislead ; a variety of matters influencing the expense of the works in such uncertain operations as well work ; framing the contract so as only to pay for what is actually done is fairest both to the employer and contractor, and is therefore adopted in this contract. In the following work it was expected that water would be found about 85 to 90 feet from the surface ; experience showed that 81 feet was the point where the spring was entered. Contracting, therefore, for 50 feet certain, and then at an increasing schedule of prices, was considered the best method of proceeding ; here all things were found by the contractor.

Specification of certain works required to be done in sinking and steining a well for ———, of ———, to be excavated *in a field* called Great Daws, in a part of it to be pointed *out to the contractor.*

*Excavator.*—To excavate a well 4 feet diameter in the clear when finished and steined, to be sunk as deep as directed by Mr. Swindell, architect, under whose superintendence the work is to be done; provide all buckets, tackle, ropes, and windlass necessary for removing products of the excavation, which are to be placed or piled in a part of the field where directed, within 60 feet of the opening of the shaft; provide all shoring, boring augers necessary for feeling the work, as the excavation proceeds; remove all extraneous water, and do all things necessary for completing the works.

*Steining.*—The bricks to be new, sound, hard, square, well-burned gray stocks. The steining to be of 4½-inch work, and to be laid dry in the most careful and approved manner, between the courses laid in cement, which cemented rings are to be three courses thick, and to occur as close as may be necessary for the stability of the work, never exceeding 5 feet apart. Where land-springs occur, or in bad ground, the steining to be executed entirely in cement, and puddled behind. The first 4 feet from the surface to be steined in 9-inch work set in cement. The best Roman cement and sharp Thames sand to be used; the former to be gauged with half sand.

The contract and conditions do not differ materially from those last given; and in both is a clause whereby the employer engages to pay the contractor, and to fulfil his part of the agreement, on receiving a satisfactory certificate from the architect that the works are going on well.

### Some Remarks on the Wells for supplying the Fountains in Trafalgar Square.

From the position of the fountains, the discussions their appearance gave rise to, and the recentness of their execution, this national work is well worth attention: a descriptive sketch shall, therefore, be given of, first, the wells; secondly, the engine for raising the water. The water is supplied by two wells, connected together by a tunnel, or driftway, which is

run in the clay at a point lower than the position in the wells
to where the water rises; the wells and tunnel are calculated
to hold, when the water has attained its maximum height,
122,000 gallons.   One of these wells is in Orange Street, and
about 180 feet deep, with a diameter of 6 feet; the other is
in front of the National Gallery, it is of very nearly the same
depth, with a diameter of 4 feet 6 inches; the driftway
is 6 feet diameter, and occurs about 5 feet from the
bottom of the shafts; this driftway, or tunnel, is horizontal.
The boring, which commenced at the bottom of the shaft, was
continued to a greater depth in the well opposite the National
Gallery than in the one in Orange Street; the total depth
from the surface being, in one case, 395, while, in the other,
the depth was about 300 feet.   The use of the tunnel is
almost self-evident; it acts, as may be supposed, as a reservoir
to store the water while the engine is not at work; thus
insuring a sufficiency to supply the pumps even should they
draw the water away from the well faster than the same is
supplied by the spring.   The strata passed through by the
two wells may be thus represented: the authority is a section
published in the " Illustrated London News."

| One in front of National Gallery. | One in Orange Street. |
|---|---|
| Made ground . . . 9 feet | Made ground . . . 15 feet. |
| Gravel . . . . 5 ,, | Gravel . . . . 5 ,, |
| Shifting sand . . . 7 ,, | Loam and gravel . ·. 10 ,, |
| Gravel . . . . 2 ,, | London clay . . . 145 ,, |
| London clay . . . 142 ,, | Thin layer of shells. . |
| Thin layer of shells. . | Plastic clay . . . 30 ,, |
| Plastic clay . . . 30 ,, | Gravel and stones . . 10 ,, |
| Green sand, pebbles, &c. 11 ,, | Green sand . . . 35 ,, |
| Green sand . . . 42 ,, | Chalk, which, according to the |
| Chalk . . . . ,, | above, is distant from the surface |
| Total depth to chalk is therefore | 250 feet, the bore being continued |
| 248 feet, and total depth of well | to a total depth from surface of |
| and bore 395 feet. | ground of about 300 feet. |

The pumping engines are on the Cornish plan, though
made in London; one is of the usual construction, having

a beam, and the other, which is chiefly required as a reserve engine, is direct acting, that is, the beam is dispensed with, and the piston-rod of the engine connected by rods directly on to the pumps. Though the mode of action of these and other Cornish engines cannot be thoroughly explained without complicated drawings, yet the following will give an idea of its action, and, if attentively read over, while watching the working of one of these sort of engines, cannot fail of rendering the action of the machine clear. The steam, as before remarked in the Chapter on Pumps, &c., acts on the piston, if the engine be a beam engine, only during its down stroke; to regulate this, a valve is required, situated so as to open and shut the communication between the steam in the boiler and the top of the cylinder, in which the piston slides, there is also a valve opening a communication between the top and the bottom of the cylinder; now, should this be open, the steam valve being shut, the piston will rise, for the counterweight at the opposite end of the beam will pull the piston upwards, the steam circulating from the top to the bottom of the cylinder. A third valve is also required to open and shut a communication between the bottom of the cylinder and the vessel in which the steam is condensed; so that the steam, which in the down stroke of the piston caused its motion, is, after having changed its position, by the opening of the equilibrium valve, from the top to the bottom of the cylinder, then by the opening of the exhaust valve, let into the condenser. We are now in a position to comprehend the double stroke of the engine; supposing the steam valve and exhaust valve, opened by the preponderance of weights, released by the cataract, or instrument for regulating the distance between the strokes, a downward motion of the piston commences, when about one-third of its stroke, or less, the motion of the engine shuts the steam valve, the exhaust valve remaining open; the expansion of the steam shut in the upper part of the cylinder causes the piston to continue its motion to near the bottom of the cylinder, just previous to where it stops the exhaust valve is shut. The engine now is quite stationary

at the proper period the cataract releases the equilibrium valve weight; the valve rises, and the up stroke is performed by the aid of the counterweight, as before remarked. On the engine shutting the equilibrium valve, the up stroke of the piston is stopped, and, after a definite period, by the action of the cataract, the steam valve is again opened. The steam being condensed, the under side of the piston, it is almost needless to remark, is in vacuo during its down stroke; this condensing apparatus is not common to the pumping engine alone, but is usually applied in all large engines. The advantage of condensation is equivalent to an increased pressure of steam in the boiler, for it is manifestly the same thing in effect, to withdraw a certain resistance opposed to the motion of the piston, as to add additional urging force, the resistance being retained; and if, further, this resistance can be removed with less expenditure than the increased pressure can be gained, it is clear its removal is more desirable than increasing the pressure of steam. To condense the exhaust steam, we require plenty of cold water; to increase the boiler pressure, we require more fuel, and circumstances will determine which of these two it will be best to expend.

### *Well, Kentish Town, for the Hampstead Water Company.*

This work, now in course of execution, is carried on under the superintendence of H. P. Hakewill, Esq., the Company's engineer; the diameter of the well, which is not quite the same all the way down, is of more than usual magnitude, and, as a large supply of water will be required, advantage is taken, both of the sand springs of the plastic clay formation, and also of the water to be derived from the chalk, to insure a plentiful supply from which the well is dug (not bored) into the latter formation, it being considered that, as little or no infiltration takes place from the hard chalk, in case no large *fissure* should be met with, a great length of the flint lines *always found in the chalk* should be exposed, as it is along *these rows of flints* that the water will percolate into the

well. The sand springs can be shut out of the well at pleasure, the iron cylinders which pass through them having apertures for that purpose. It is obvious that, in digging through chalk in the manner above indicated, the water percolating into the well must be pumped out as fast as it enters. In the example above, the steam engine is already erected; the lowest lifting pump is lowered as the excavation deepens, and, till the supply of water is sufficient to keep the engine at work at a proper speed, the sinking of the well will be persevered in. When the author visited the works, the total depth from the surface was about 370 feet; very little water was then entering the well from the chalk; the engine (a Cornish one) was making one stroke in about two minutes, but, at that slow speed, was only drawing air, except from the sand spring, some water of which was being pumped up during the time that the author was in the well. The steining of this well is nine inches thick, the bricks being set all the way in cement; the whole thickness was not executed simultaneously, the back steining being executed first; the iron cylinders, previously alluded to, are of wrought-iron plates, riveted together, and quite flush on the outside. The brick steining was executed in 14-inch work for some distance from the surface of the ground to exclude land springs, and the whole is suspended, as is usually done, where sand occurs in place of a good foundation. The strata passed through are as follows; (the reason no depth in the chalk is given is because the work is not yet finished.)

|  | Feet. | Inches. |
|---|---|---|
| Yellow clay . . . . . . | 28 | 0 |
| Blue clay . . . . . . | 207 | 0 |
| Plastic clay . . . . . . | 36 | 6 |
| White sand, pebbles, and water . . | 0 | 6 |
| Hard dark sand . . . . . | 2 | 0 |
| Mottled clay and green sand . . | 1 | 0 |
| Hard sand . . . . . . | 3 | 0 |
| Hard dark sand and veins of clay . . | 0 | 0 |

|                |   |   |   |   |   | Feet. | Inches. |
|----------------|---|---|---|---|---|-------|---------|
| Running sand   | . | . | . | . | . | 6     | 6       |
| Pebbles        | . | . | . | . | . | 1     | 6       |
| Hard sand      | . | . | . | . | . | 10    | 0       |
| Very hard sand | . | . | . | . | . | 4     | 0       |
| Hard sand      | . | . | . | . | . | 11    | 0       |
| Chalk          | . | . | . | . | . | —     | —       |

The total depth of the well, as before stated, was 370 feet, when the author visited it, and the depth to the chalk above is 320 feet. The surface ground around this well is 185 feet above low-water mark of the Thames, at London.

Situated in this well are three pumps, the two lowermost of which are lifting, the uppermost of the series being a forcing or plunger pump; the two lower lifts are 110 feet each, with 12-inch barrels, and 13-inch rising mains; the latter being larger, so as to allow of the bucket of the pump being drawn up through the main. The diameter of the plunger is $11\frac{1}{2}$ inches; the pumps, being worked from one end of the engine beam, as is usual in large pumping engines, have all the same stroke, which is nine feet. The engine need not here be described, it being similar in principle to all Cornish engines, which sort of engine has been before alluded to.

*Artesian well lately sunk at Camden Station.*

This work differs from the two former examples in the description of steam engine and arrangement of the pumps, for, as the engine is required to do other work besides pumping, the ordinary pumping engine is inadmissible. The well, the pumps, and the motive power shall be mentioned in order. First, the well, which is sunk to a depth of 180 feet, of a diameter in the clear of 9 feet 6 inches, the steining of which is executed all the way down in cement. For 28 feet from the surface, unusual pains are taken to exclude land springs, &c.; they are, first an inner steining of half *brickwork set in cement;* next, segmental cylinders of iron;

next, a thickness of about 9 inches of concrete; and lastly, behind all this, a 9-inch steining of brickwork. From the depth of 28 feet from the surface, the steining is 14 inches thick, and bonding curbs of iron occur at intervals. The boring, which commences at a depth of 180 feet from the surface, is continued for 220 feet, and is of a diameter of 12 inches. The section of ground passed through during the progress of this work is as follows: the water rises in the well 36 feet from the bottom, or 144 feet from the surface of the ground. This well, which is sunk in a very creditable manner, was executed by Mr. Paten, of Watford; the pump work and engine were made by Messrs. Bury, Curtis, and Kennedy, of Liverpool.

*Section of Well, Camden Station.*

|  | Feet. |
|---|---|
| Made ground . | 9 |
| Loam and gravel . | 6 |
| Black earth . | 3 |
| Blue clay . | 144 |
| Mottled clay . | 36 |
| Green sand . | 1 |
| Pebbles . | 2 |
| Mottled clay . | 8 |
| Plaster clay . | 17 |
| Loam and sand . | 5 |
| Pebbles and sand . | 2 |
| Bed of flints . | 1 |
| Chalk . | 166 |
| Total depth . | 400 |

The boring pipes are continued 60 feet up the well, the water being admitted from them by a sluice, which is situated about 4 feet from the bottom of the shaft. This sluice is worked by a handle placed above the water level; the pipes *themselves* are steadied by stays, which are secured to the

D 3

brickwork of the well.   Our next consideration relates to the
pumps, of which there are two pairs, each pair consisting of a
lifting pump for the lower, and a plunger pump for the upper
lift.   This arrangement of four pumps is used to insure
uniformity of motion, for the steam engine being double
acting, that is, giving out as much power during the up as the
down stroke of the piston, requires an equal resistance for
each stroke.   The lifting pumps empty their water into a
wrought-iron cistern, which is about 4 feet deep, and 3 feet
2 inches over, the back of it being curved to  suit that of the
well: thus the plan of the cistern is that of a sector.
Dipping into this cistern are the suction pipes of the plunger
pumps; the plungers are 8 inches diameter, and the buckets
of the lifting pumps, 8¾".   The rising mains of the latter are
11 inches diameter; the mains of the plunger pumps are of
course smaller, the working parts of the pumps being outside,
and not surrounded by the mains, as the lifting buckets are.
For the same reason, only one main is required for the
plunger pumps; at the bottom of this is situated an air
vessel, which is an apparatus whereby a constant uniform
stream of water flows from the main; its construction is very
simple.   It may be described as a vessel larger than the rising
main, and into which, through an air-tight opening at the
upper end, the main dips so as nearly to touch the bottom of
the vessel: water from the pumps being ejected into this
vessel will compress the air included in the space between
the orifice of the main and the upper part of the vessel ;  the
elasticity of this compressed air will therefore continue to
drive the water which has risen above the orifice up the main
during the instant that the pumps are stationary, which is at
the period of the change of stroke.

The motive power for working the pumps consists of a
high-pressure beam engine of the usual construction, which,
as before remarked, performs other work as well as pumping.
*This engine is* twenty-seven horse power.   The power re-
*quired for raising* the water can be determined by any one, as

all the data are here given for the calculation, it being borne in mind that the cistern into which the water is forced is 40 feet above the surface of the ground. The steam engine is 4-feet stroke, and the motion of the pumps being taken off the beam, at points respectively midway between the centre of the beam and the two ends, gives as the stroke of the pumps 2 feet. The speed at which the engine travelled when the author visited the works was twenty-one revolutions per minute. The boilers for this engine are of the Cornish description; they are 5 feet 10 inches diameter, and 22 feet long; one at a time is sufficient for working the engine, the other being a spare one. The strength of the spring was tested when the works were completed, and the following is the result. The engine began work at nine o'clock in the morning, and, by continual pumping till twelve, lowered the water 11 feet 6 inches; by three o'clock, the engine still working, the water was lowered 6 inches more; at that point no further diminution was remarked. The water is remarkably soft, and for domestic purposes is excellent, but it does not answer for supplying the boilers of the locomotive engines. Annexed is an analysis of the water of the well under consideration, as also of that drawn from the wells belonging to the Railway Company at the Watford and Tring stations; all these are sunk in the chalk formation, yet a great difference exists in the constituents of the impurities of the water. The analysis in all cases was made by R. Phillips, Esq.

| Situation. | Sulphate Soda. | Carbonate Soda. | Muriate Soda. | Carbonaceous Matter and Trace of Silica. | Sulphate Lime. | Carbonate Lime. | Total Solid Matter. |
|---|---|---|---|---|---|---|---|
| | | | | | | | Grains. |
| Camden . | 13·00 | 17·60 | 11·10 | 2·30 | ... | ... | 44·00 |
| Watford . | ... | ... | 1·90 | 1·32 | ·94 | 19·54 | 23·70 |
| Tring . . | ... | ... | 1·38 | 1·61 | 1·09 | 14·72 | 18·80 |

The quantity of water experimented upon in the above analysis was one gallon in each case. The above particulars of the Camden well were obtained, by the kindness of R. B. Dockray, Esq. C.E., through the means of documents in the Engineer's office, Euston Station, and personal examination of the pump work, &c., in the well itself.

*Well, Hanwell Lunatic Asylum.*

This work, which was carried on about five years back, is remarkable for the great rise of the water; indeed, the district is well suited for a purely Artesian well, and in this case it is quite evident that, had the well been entirely bored, the same amount of water would have been obtained, deducting the retarding action caused by the friction of the water against the sides of the bore pipe. In the " Sixty-eighth Report of the Visiting Justices of the County Lunatic Asylum at Hanwell," is a notice of this well, from which the following is compiled. The section of the ground passed through is as follows :—

*Section of Well, Hanwell.*

|  | Feet. | Inches. |
|---|---|---|
| Vegetable soil, sand, and gravel . . | 20 | 0 |
| Blue clay, with some brick clay on the top, and veins of stone occurring at intervals . | 168 | 0 |
| Indurated mud and sand . . . . | 22 | 0 |
| Pebbles and shells . . . . . | 2 | 0 |
| Mottled clay . . . . . . | 23 | 0 |
| Sand and water . . . . . | 2 | 0 |
| Mottled clay . . . . . | 13 | 0 |
| Indurated sand and mud . . . . | 9 | 0 |
| Clay . . . . . . . | 8 | 0 |
| Green sand and clay . . . . | 8 | 0 |
| Bed of hard oyster shells . . . | 3 | 6 |
| Pebbles . . . . . . | 3 | 6 |
| Flint stones bored into . . . . | 8 | 0 |
| *Total depth* . . . . | 290 | 0 |

In sinking this well, the shaft was carried down for the first 30 feet of a diameter of 10 feet; from that point the diameter was 6 feet to that part of the mottled clay in which the iron cylinders were affixed. The cylinders were then lined with a brick steining, and the boring was continued from thence to the bed of flints in which the work was discontinued. The supply of water from the sand spring rose to within 16 feet of the surface of the ground, from the pebbles overlying the flints, the water rose to a further height of 8 feet, and from the bed of saturated flint stones, the water rose so as to overflow the surface at the rate of 100 gallons per minute; and, 26 feet above the surface, the water overflowed at the rate of 23 gallons per minute. The supply proving so great, the large diameter of the first 30 feet of well was found useless, so a rising main of iron was fitted to a cap which was inserted at that part of it where the 6 feet diameter commenced. The temperature of the water is about 55° Fahr., and contains in each gallon 48 grains of solid matter, consisting of salts of lime and soda, with a trace of iron.

### Messrs. Verey's Well, Kilburn.

This work, which was executed under my superintendence, has been very lately completed; the diameter in the clear for 250 feet is 4 feet; after that, boring commences, and is carried down to the sand spring of a diameter of 8 inches, and to a total depth, from the surface, of about 280 feet. The rise of water is to about 150 feet, or rather less, from the surface. The original intention in sinking this well was to have bored after attaining a depth of 200 feet (the water level being well known in this district); but, had such intention been persevered in, fears were entertained that the 50 feet of water in the well, being only the upper head of the spring, would be insufficient to supply the wants of the brewery : the extra 50 feet of digging was therefore ultimately determined on, and the experiment detailed at the

end of this proves the view taken to be correct, for, if pumps be fixed at too high a level above the spring, the hydrostatic pressure of water is insufficient to cause the water to rise in the well fast enough to supply the pumps, even should they be small ones. The works were commenced in April last, and for 10 feet down the brickwork was in cement, and 9 inches thick, to exclude land drains from the well : about 25 feet were executed the first week, and after that the work averaged about 20 feet to the week, some weeks it being a little more or a little less; the stiffness of the clay and the claystones, or septaria, which were found at intervals, affecting the speed of the work. The London, or blue clay, which was soon arrived at, extended to a depth of 235 feet; the mottled clay, pebbles and sand followed much in the order of the sections before given, while in the mottled clay the steining was not left unsupported with such impunity as in the blue clay : it is of a more soapy or slimy nature, and exposure to the air, together with these properties, renders it more likely to let the brickwork slip. Very little need be remarked on the execution of the steining, after what has already been said on this subject, suffice it that the work was laid partly in cement and partly dry, and of a thickness of 4½ inches. The cement used was blue lias (Greaves's patent), and the bricks partly stocks and partly malm paviors. The cement was used stale and mixed thin, since, if not, it would have become partially set in being conveyed down the shaft to the workmen, as, when near the full depth, the time of journey down the well was nearly of three minutes' duration. The boring pipes were of wrought iron, the lower lengths perforated, the junctions being tinned in the usual manner. On obtaining the water, the quantity was tested by the aid of a temporary pump, the application of which is also useful in clearing the work, and ascertaining if any sand has blown into the well ; this pump was an ordinary *lifting pump,* of 6 inches' diameter, and working with a *stroke in the barrel* of about 9 inches, the rising main was

bolted directly over the pump barrel, which by it was thus suspended in the water; the main, on its passage up the well, was steadied by timbers, the rods worked by this arrangement in the rising main, and were carried to the top of the well, where motion was given to them by eight men ; the result of the experiment was that the pump which threw about 24 gallons per minute lowered the water about 33 feet, but no further, thus proving the strength of the spring when a head of 33 feet of water was taken off. Here the advantage of drawing the water from a point underits surface, as far as practicable, is made manifest; indeed, the question is one turning on a law of hydrostatics, well known and easily calculated. As the pump work in this well was not executed under my directions, it would be invidious of me to make any remarks, and it must suffice to say that the pumps are three throw ones, and very good of their kind. The cost of executing this well, exclusive of the pump work, both temporary and permanent, was about £200.

*Well, Hampstead Heath, belonging to the Hampstead Water Company.*

This well was sunk in the year 1833, down to the main sand spring a depth of about 320 feet, and of a diameter of 7 feet. About a year and a half since, as a rather greater supply of water was desired, a bore was carried into the chalk. The steining of the well is 9-inch work, laid dry, between rings set in cement; the back steining has its cement rings midway between those of the front steining. The lower part of the steining is held up by four tie rods, which are bolted to cast-iron curb let into the brickwork some distance up the shaft. The section of the ground passed through during the two operations of digging and boring is as under. The situation is on the lower heath, where there is no sand.

|  | Feet. |
|---|---|
| Yellow clay . . . . . | 30 |
| *Blue clay* . . . . | 250 |

|                                       | Feet. |
| ------------------------------------- | ----- |
| Plastic clay . . . . .                | 40    |
| Sand . . . . . .                      | 49    |
| Bed of flints very thin, chalk hard . | 40    |
| Do.    soft, with water . .           | 4     |
| Chalk hard, no water . . .            | 28    |

From this section it will be seen, that passing the chalk spring the hard chalk underlying it supplied no water, thus proving a remark previously made that, in obtaining water from this formation, when it is very hard, none can be expected, till long lines of flints, fissures, or softer chalk, is arrived at. Mr. Hakewill, the engineer under whom this boring was carried on, took pains to ascertain that no water was rising from the hard chalk under the spring; and this fact influenced his proceedings in the matter of the well at Kentish Town, previously alluded to. The water is raised in this well by means of three lifting pumps, situated at different heights up the shaft. Each lift averages about 100 feet, and the sizes of the pumps are 8⅝ diameter of bucket, by a length of stroke of 2 feet 3 inches; the lowest pump is slung in the water by having its rising main, which is of larger diameter than the bucket, secured by flanches and bolts to cast-iron girders, arranged for that purpose in the well, where the two lower lifts terminate. The pump rods pass through stuffing boxes from inside the rising main. The cisterns, from which the second lift draws from the first and the third from the second, are very small, being only branched from the rising main, and in capacity but little larger in diameter than the pump barrel, just in fact sufficient to hold a supply for the higher lift. The rods, when inside the mains, are steadied by triangular guiding pieces encircling them, and, where outside the mains, they pass through wooden cleets, which are secured to cast-iron girders. Situated at the top of the well is a cast-iron framing, with upright guides. *Between* these guides work cast-iron wheels; *to the axle of these* wheels the pump rods, and also the con-

necting rods from the cranks are attached; thus, though the tendency of the crank in its revolution is to pull the rods from a vertical line, the effect of the pulleys is to keep their motion in a straight one. A plan of the position of the steam engine, which is of the usual beam-engine construction, is shown in Plate 13, Fig. 1, and a plan of the lying shaft, and three-throw crank, is represented in Fig. 2. The three-throw crank, which in its revolution gives motion to the pump rods, is itself put in motion by the wheel *a*, which is turned by a smaller wheel, or pinion, which is situated on the crank shaft of the steam engine, directly above. The wheel *á* is for the same purpose as *a*, but to suit a different speed; so of course the pinion which gears into it must be necessarily larger, thus causing the ratio between the two wheels to be different. The relative speed of the engine to the lying shaft, as worked when the larger spur wheel is in gear, is about 1 to $2\frac{1}{2}$, and when the smaller, as 1 to not quite $1\frac{1}{2}$. Referring to Fig. 1, A is a stone slab, on which the engine is fixed; B the fly wheel and pinion race; c the position of the boilers, one being sufficient for working the engine, the other being a reserve; D, the grating above the steps which leads to the well and place wherein works the lying shaft; the stairs, E, lead to domestic arrangements above; F is the coal-hole.

Little description is needed for Fig. 2. The shaft spur wheels on it, and three-throw crank at the opposite end, directly over the well, are clearly shown. The pumps, as evidenced by the position of the shaft, are not fixed on the line of the diameter of the well. The reasons for this are, to allow a sufficiency of clear span in the well, while repairs, &c., are going on, besides diminishing the space of the various girders, &c. This arrangement of fixing pumps is always adopted when practicable.

### *Well, Fort Regent, Jersey.*

This work has been described by Major H. D. Jones, R.E., in the "Professional Papers of the Corps of Royal En-

gineers." The following quotation from parts of his descrip-
tion will no doubt be acceptable to the reader :—" Fort Regent
was constructed during the late war between Great Britain and
France. The works were commenced about the year 1805.
The fort is erected upon the Town Hill, a bold promontory to
the south of the town of St. Helier, which it commands most
completely, the town being built at the foot of the rock. The
summit of the hill was above 170 feet above the level of high
water. In its character it very much resembles Gibraltar, a
bold rocky feature, rising abruptly from the sea, and having
scarcely any perceptible connection with the hills to the north-
ward and eastward, which encircle the town in those directions.
The South Hill is formed of compact sienite, weighing 165 lbs.
per cubic foot. The rock is stratiform, with vertical joints ;
the general direction is east and west. There were no springs
upon the surface of the hill, nor anything indicating on the
face of the scarped rock that it contained such an abundant
supply of water ; it must, consequently, have been upon the
conviction that water would be found by sinking to the same
level as the water stood at the Pigeon Pump, in Hill Street,
(240 yards distant from the point where the well in the fort
has been sunk,) that Major Humphry, the commanding engineer,
was induced to recommend the attempt being made. The
operation, although it cost much time, labour, and expense,
has been most completely successful. After sinking through
234 feet of compact rock, and upon firing a blast, the spring
was laid open, the water from which immediately rose in
the shaft to a height of 70 feet, and has rarely since been
lower. During the progress of the work, water had been
found at different points, but not in any quantity sufficient
to retard the workmen, until the lucky blast above mentioned,
when it poured in like a torrent, to the great astonishment of
the miners who were suspended in the bucket, waiting the
effects of the explosion." The temperature of the water in
*this well is* 50° Fahrenheit. Some further memoranda from
*the same source are* :—" The following details, extracted from

the office books, will afford some idea of the difficulty of the operation, and the time and labour consumed in sinking the well. The work was commenced in December, 1806, and continued night and day until November, 1808 :—

| Commenced 1806. | Number of Miners per month. | Feet sunk per month. | Price paid per foot. |
|---|---|---|---|
| | | | Livres. |
| December ........ ... | 14 | 13 | 60 |
| 1807. | | | |
| January ............... | 12 | $8\frac{1}{2}$ | 72 |
| February ............... | 12 | 3 | 96 |
| March .................. | 12 | 9 | 108 |
| April ..................... | — | — | — |
| May ..................... | 12 | 5 | 120 |
| June..................... | 12 | 11 | 108 |
| July ..................... | 12 | $8\frac{1}{2}$ | 108 |
| August.................. | 12 | $10\frac{1}{4}$ | 111 |
| September ............ | 12 | 10 | 108 |
| October ............... | 12 | $9\frac{1}{4}$ | 108 |
| November ............ | 12 | 9 | 108 |
| December .............. | 12 | 9 | 108 |
| 1808. | | | |
| January ............... | 12 | $9\frac{1}{4}$ | 108 |
| February ............... | 12 | $7\frac{1}{2}$ | 108 |
| March .................. | 12 | $10\frac{3}{4}$ | 108 |
| April ................... | 12 | 9 | 108 |
| May ..................... | 12 | $12\frac{1}{4}$ | 108 |
| June..................... | 12 | 13 | 108 |
| July ..................... | 12 | 10 | 108 |
| August.................. | 12 | $11\frac{3}{4}$ | 108 |
| September ............ | 12 | $9\frac{1}{4}$ | 108 |
| October.................. | 12 | 9 | 108 |

*Average cost,* 10*s.* per foot.—Total expense, £2599 8*s.* 7½*d.*

" There were expended, during the progress of the work, of the following articles the under-mentioned quantities, viz. :—

|                |   |   |   |   |   |              |
|----------------|---|---|---|---|---|--------------|
| Candles        | . | . | . | . | . | 976 lbs.     |
| Coals          | . | . | . | . | . | 1659 bushels.|
| Gunpowder      | . | . | . | . |   | 2848 lbs.    |
| Lamp oil       | . | . | . | . |   | 82 gallons.  |
| Miners' tubes  |   | . | . | . |   | 9852    „    |

" There are two cisterns capable of holding 8000 gallons each. The water is pumped into them by machinery, to be worked either by horses or men, the same machinery being applicable to the working of a bucket in case the pump should be out of order. The pump is 4 inches' diameter, with brass bucket and valves, with 195 feet of wrought-iron rod, jointed every 10 feet, and eighteen 10-feet lengths of $5\frac{1}{2}$-inch iron pipe. Cost, £495 15s."

" The machinery for working a bucket from the horse wheel, independent of the pump, consisting of a barrel on the horizontal shaft, with clutch-box, lever and pulleys for leading the ropes, cost about £35." " The total expense, including the labour in fixing machinery or incidental expenses, amounted to £667 15s. Thus, for a sum little exceeding £3000, there is obtained for the garrison an inexhaustible supply of excellent water. Twenty-four men working for two hours, without fatiguing themselves, can with ease pump into the cisterns 800 gallons of water."

### Well, Kingsbury, Middlesex.

This work was executed in order to supply seven or eight houses proposed to be built adjoining. The diameter of the well is 4 feet, the steining being half brick thick, with rings, set in cement, occurring every 5 feet. The London, or blue clay, was entered about 15 or 16 feet from the sur-face, and the total depth to the main spring in the plastic *clay, 79 feet; the* water rises 22 feet, thus making a total

depth from the surface of 57 feet. During the digging of the well, there were found in the London clay many pieces of decayed wood, a few shells, and specimens of septaria, or the stone from which Roman cement is made. The pumps for raising the water are situated about 4 feet above the surface of the latter, and their suction pipes dip within one yard of the bottom of the well. A side view of one of these pumps is shown in Plate 11, Fig. 1; the junction or scarfing of the rods is seen in Fig. 2; the guiding rollers, and cleet for securing the rising main, are represented in Fig. 4; these guides occur every 10 feet up the shaft. The pumps are situated as usual, not on the line of the diameter, so that a section of the well on that line, as in Plate 12, shows the two pumps in elevation; they are bolted to oak girders, which tail into the sides of the shaft about 1 foot 3 inches each way, the brickwork around the same being laid in cement; the tailing of the girders necessarily cannot be seen in the section, as that is on the diameter of the well. The rising main is of copper, and bolted to a cast-iron branch pipe from the two pumps; about 2 feet under the pumps is a close stage of oak, thus rendering access to the pumps easy at all times. The steam engine for working these pumps is situated directly over the well, and, by means of a beam, imparts motion to the pump rods; one pump, therefore, has its bucket working upwards, while the other has the same working downwards. Plate 16 shows an engine of similar power to the one under notice; the arrangement is almost the same, the only difference being in the position of the cylinder and beam. The cylinder is shown here outside the framework, the beam being between the pair of columns. In the Kingsbury engine this is reversed; but it was found that, as the works were so small, a certain degree of difficulty was thereby occasioned in oiling and attending to the parts; therefore, in engines that have since been made under the author's direction, the arrangement shown in the plate is adopted. Referring to Plate 16, the pump rods, as they

rise from the well are marked *a a;* on the engine crank shaft
*b* is a pinion *c,* this gearing into the spur-wheel *d* turns the
crank which gives motion to the beam *e;* it is manifest any
degree of relative speed can be given by these toothed wheels.
A plan of the engine house and cottage attached is seen in
Plates 13 and 14; little remark need be made on it, save
that over the engine house is a cistern capable of holding
1600 gallons ; in the office is situated the regulating cock to
the main.    The domestic arrangements are self-evident, and
the reason the scullery is lighted by a glass door instead of a
window is because no side light was admissible.    Plate 14
shows the elevation of the building.    The work was carried
on under my superintendence, the pumps being manufactured
by Mr. Fowler, of Dorset Street, Fleet Street.    To prevent
smoke, coke is usually burnt under the steam boiler; the
pumps work at a slow speed, and throw up about 600 gallons
per hour, the combustion of fuel being very little to accom-
plish this.    The results of this engine, and the small cost of
the whole, corroborate the opinion before expressed, that steam
is applicable, even should the scale be very small, to pumping
purposes.    The cost of this well was about £56, being ex-
clusive of the engine, pumps, &c., &c.

## CHAPTER VII.

### STRATA OF ENGLAND AND WALES IN REFERENCE TO ITS SPRINGS.

THE most superficial observer must be aware that the com-
ponents of the surface of the earth greatly vary in different
situations; in some places, hard, crystalline, unstratified rocks
*make their* appearance; in others again, a soft stratum, evi-
*dently bearing the* character of having been deposited in

layers, will be found. This disposition, a little closer examination will show, is not the result of an accidental confusion, but follows from an order of super-position which it has been the province of geology to unravel. The purport of the present chapter is to lay before the reader the relation of these various substances composing the earth's crust, as connected with the subject of springs; and, because the surface of the crust may be taken as an index of what may be expected underneath, it is desirable to give the order in which the various rocks and deposits are found. The reason that in all cases the same distance does not intervene between the lower rocks and the earth's surface is simply from the fact of the inclined, and not horizontal, position of the strata; it is needless to point out the advantage of this arrangement, for the wisdom of it is obvious. Although the lower rocks outcrop and show themselves in many places on the earth's surface; and further, though some usually intervening rocks may be, and often are, missing between some of the upper and under beds of the series, yet, except under very unusual circumstances, will any of the upper ones underlie the deposit or rock which the order of super-position places them above. Descending from what geologists consider the latest formation, a section of the earth's crust may be represented as follows: a great many subdivisions being, of course, omitted.

### *Formations above the Chalk.*

Vegetable soil, gravel, crag sand, London clay, septaria.
Plastic clay, with beds of sand.

*Cretaneous Group.*—Chalk, chalk marl, upper green sand, gault clay, lower green sand, weald clay, iron sand.

*Oolitic System, Upper Series.* — Purbeck beds, Portland beds, calcareous sand, Kemmeridge clay.

*Middle Series.*—Coral rag, yellow sands, calcareous silicious grits, Oxford clay.

*Lower Oolitic Series.* — Cornbrash limestone, and forest marble, great oolite, or softish freestone, layers of clay,

stonesfield slate, fuller's earth, clay, sandy limestone, or inferior oolite.

*Lias Formation*—which consists of limestone beds, divided by layers of clay.

*New Red Sandstone Group*—consisting of variegated marls, sandstones, congromerates, gypsum, rock salt, bone red, or dark-coloured limestone, blue and blackish limestone, alternating with clay and marl, &c.

Magnesian limestone.

*Carboniferous Group.*—Coal measures, sandstones, clays, shales, ironstone, millstone grit, mountain limestone.

Old Red Sandstone Formation.

*Silurian System*, comprising argillaceous limestones, sandstones, quartzose flints, flagstones, schist.

*Cambrian System*, or inferior stratified rocks of clay slate— mica slate, with dark-coloured limestones, sandstones, &c.

*Plutonic Rocks*, as granite, sienite greenstone, hornblende, serpentine, &c.

It is not here intended to say more on the properties of the various substances mentioned above, excepting so far as connected with the consideration of springs in them. The vegetable soil comes first under review; such soil, if it rest on gravel or sand, will always be dry; but if it rest on clay, or any other retentive strata, will, unless well drained, be a complete swamp; on such a substratum rests those soils where the springs are within a few feet of the surface; should, however, gravel or sand succeed the surface soil, no water can be expected in it, till a retentive seam of clay be met with, or other impermeable matter. When sand, as at Hampstead, rests on London clay, very little difficulty is occasioned in getting a sufficient water supply from it; such land-springs are, from their nature, very variable.

Gravel oftentimes rests on porous chalk, in many parts of Hertfordshire, for instance; here we can expect no water in *the* gravel, but must sink to the saturated point of the chalk.

*London Clay.*—In this formation there are few springs, and

though, by chance, one may be met with, no one would think of sinking a well in the London clay in full anticipation of getting water, till that formation was passed through, and the beds of sand in the plastic clay formation were entered, in which there is almost an unlimited supply.

*Cretaneous Group.*—The quantity of water in this group is enormous; the lower portion of the chalk itself, as far as the denseness of the material will allow, is fully saturated; all fissures in it are completely full, forming, literally, subterranean rivers. The strata directly under the chalk, consisting of retentive clay, will make it appear clear to all why the lower portions of this formation should contain so much water. The long lines of flint in chalk have been remarked on before, as favouring the percolation of water, and so has the fact that, in the London chalk basin, those circumstances exist that are required to insure the success of sinking Artesian wells. When wells are sunk in the lower greensand formation, water may be met with where clay seams occur; the water which supplies the deep-seated springs is held up by the weald clay under the sand. The water supplied by the iron sand is generally arrived at by sinking deep wells; it is also often impregnated with iron.

In the upper oolite system little water can be expected in the impermeable beds of Perbeck and Portland stone, except in fissures; under the Portland bed, however, is porous matter, and the water absorbed by it is retained by the underlying clay, thus rendering it accessible. In the middle oolitic series, the Oxford or clunch clay is the retentive medium, and wells must be sunk to the saturated portions of the overlying porous matter. In the Oxford clay itself are few springs. The lower oolitic formation has water retained by clay seams. In the cornbrash limestone and forest marble the wells are not very deep; under the great oolite, the fuller's earth clay retains the water. The limestone itself is porous to a certain extent, therefore wells must be sunk in it

to its line of saturation, or its junction with the clay underneath.

The upper retentive beds of the lias formation supply water to the wells sunk in the lower oolite; and water may be met with in the upper portions of the lias formation for the same reason. Wells sunk in the lower portions of the lias formation have water retained in them by the upper marls of the new red sandstone group.

The alternations of sandstone and clay, rock salt, &c., in the new red sandstone, render water procurable in that group. The newspaper accounts of a shaft lately sunk in this formation at Gorton, by the Manchester and Salford Waterworks Company, relate that the well is seventy yards deep; there are radiating galleries from the main shaft, and the quantity of water raised by the engine equals 2,000,000 of gallons per day.

In the magnesian limestone, fissures and holes containing water must be worked for. The great quantity of water in the carboniferous group is probably known to all, it being an element which, were it not for the large pumping engines constantly at work, would greatly impede the operations of the miner; the alternating porous and retentive matter in this formation fully accounts for the appearance of the water. The mountain limestone being porous, water can only be met with when beds of clay occur; the lower portions, however, of this formation are saturated, because impervious layers separate it from the porous beds of the old red sandstone. In this latter formation there is no lack of water, its components being partly porous, with retentive intervening layers.

Owing to the stratified character of the Silurian system, water may be met with in it, and in the lower Plutonic rocks, where they show themselves at the surface, the only chance of getting water is by sinking till a fissure fully charged with water is arrived at. Such an operation as this was carried on at Fort Regent before alluded to; the rock in which

that well is sunk is compact sienite, intersected with vertical fissures.

To render the above considerations generally applicable, the following list, compiled from Davy's Artificial Foundations, has been formed.    Here the geological situation of all the counties of England and Wales will be seen alphabetically arranged, the inland and maritime counties being separated.

### Maritime Counties.

Anglesea contains clay slate, serpentine, old red sandstone, granite, carboniferous or mountain limestone, coal, sienite, and trap.

Caermarthenshire.—Silurian rocks, clay slate and graywacke, coal, old red sandstone, carboniferous limestone.

Caernarvonshire.—Graywacke, trap, gneiss, mica schist.

Cardiganshire.—Coal, millstone grit, silurian rocks, new red sandstone.

Cheshire.—New red sandstone.

Cornwall.—Millstone grit, granite, trap rocks, clay and graywacke, slate.

Cumberland.—New and old red sandstone, trap, granite, clay slate.

Denbighshire.—Clay slate, graywacke, silurian rocks, borders on carboniferous limestone.

Devonshire.—Green sand, new red sandstone, millstone grit, granite, trap, &c., clay slate.

Dorsetshire.—Plastic clay, chalk, green sand, oolitic series, lias ; limestone in Isle of Portland.

Durham. — Coal, millstone grit, magnesian limestone, mountain limestone, trap.

Essex.—London and plastic clay.

Flintshire.—Coal, millstone grit, new red sandstone, silurian rocks, trap.

Glamorganshire.— Coal, millstone grit, old red sandstone, lias.

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Gloucestershire.—Lower oolite, lias, new red sandstone, mountain limestone, old red sandstone, coal.

Hampshire.—London clay, plastic clay, chalk, green sand.

Isle of Wight.—Freshwater beds, plastic clay, whealden, green sand, chalk.

Kent.—London clay, plastic clay, chalk, green sand, upper oolite.

Lancashire.—Coal, millstone grit, mountain and magnesian limestone, new red sandstone.

Lincolnshire.—Chalk, green sand, upper, middle, and lower oolite, lias; much marsh or fenny land.

Merionethshire.—Graywacke.

Middlesex.—Upper marine, blue, or London clay, and plastic clay.

Monmouthshire.—Silurian rocks, coal, old and new red sandstone, carboniferous limestone.

Norfolk.—Crag and diluvian, chalk, green sand, and upper oolite.

Northumberland.—Mountain, or carboniferous limestone, coal, basaltic and porphyritic trap, old red sandstone.

Pembrokeshire.—Clay slate, graywacke, coal, trap, old red sandstone.

Somersetshire.—Green sand, lower oolite, lias, new red sandstone, coal, mountain limestone, clay slate, graywacke, very little chalk.

Suffolk.—Crag, London and plastic clay, chalk, green sand.

Sussex.—Chalk, green sand, upper oolite.

Westmoreland.—New and old red sandstone, trap, granite, clay slate, silurian rocks.

Yorkshire.—Coal, millstone grit, carboniferous limestone, trap, magnesian limestone, clays and crag.

### Inland Counties.

Bedfordshire.—Upper, middle, and lower oolitic series, bounded by green sand.

Berkshire.—Plastic clay, chalk, green sand, upper and *middle oolite.*

Brecknockshire.—Old red sandstone, silurian rocks, clay slate, and graywacke, carboniferous limestone.

Buckinghamshire.—Plastic clay, chalk, green sand, upper, middle, and lower oolite.

Cambridgeshire.—Chalk, green sand.

Derbyshire.—Coal, consisting of alternations of coal, sandstones, shales, ironstone beds; millstone grit, viz., quartzose grits, with shales, coal, ironstone, carboniferous or mountain limestone, trap.

Herefordshire.—Old red sandstone, silurian rocks.

Hertfordshire.—Gravel, plastic clay, chalk.

Huntingdonshire.—Green sand, upper, middle, and lower oolite.

Leicestershire.—Lias, new red sandstone, sienitic granite, trap, and graywacke.

Montgomeryshire.—Coal, trap, clay slate, and graywacke, silurian rocks, old red sandstone.

Northamptonshire.—Lias, lower oolite.

Nottinghamshire.—New red sandstone, magnesian limestone, coal on the Derby, and lias on the Lincoln side.

Oxfordshire.—Green sand, chalk, upper, middle, and lower oolite.

Radnorshire.—Trap, clay slate, silurian rocks, graywacke, old red sandstone.

Rutlandshire.—Lower oolite, lias.

Shropshire.—Coal and trap, new red sandstone.

Staffordshire.—New red sandstone, coal.

Surrey.—Chalk, green sand and whealden, and in some parts London and plastic clay.

Warwickshire.—Coal, new red sandstone, lower oolite, lias.

Wiltshire.—Small portion of plastic clay, chalk, green sand, oolitic series.

Worcestershire.—Lias, new red sandstone, sienitic granite.

The following remarks on the properties of water, may be acceptable to those who, having sunk a well, wish to ascertain

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the character of the water, or to others who may be called upon to approve or disapprove of any particular supply.

Perfectly pure water is never met with in nature; indeed, the addition of foreign matters renders it beneficial for a variety of purposes; should it be required, however, absolutely pure, recourse must be had to distillation. Its components by weight are eight parts of oxygen gas and one of hydrogen, making an aggregate of nine parts of pure water, which is quite tasteless, odourless, and colourless, is a great solvent, and absorber of gases; of some of them it absorbs its own bulk, which is one great reason why potable water should be kept free from the influence of all deleterious vapours and gases. Rain and snow water, when first collected, are considered as the purest water naturally supplied; to insure purity, they should be collected at some distance from any large town. This description of water is, however, peculiarly liable to the decomposition of the animal and vegetable matters it collects in its passage through the atmosphere. In hot weather, and in hot climates, this change takes place quickest. Spring water is modified by the strata through which it traverses, and the expressions hardness and softness refer to the relative quantity of salts with which the same is charged. The earthy impurities have the property of decomposing soap, which substance, therefore, is a criterion to judge of the softness of any water. By adding to a given quantity of any water a certain amount of soap dissolved in alcohol, the appearance of the curdy precipitate formed will at once show the relative hardness of the liquid.

Some of the substances that are usually found in spring water, are as under:—

First, carbonic acid gas. The limits in which this gas occurs, vary according to the chances the water has of absorbing it. When freely exposed, water will absorb as much as its own bulk. It may be detected by lime water, with which it forms a white insoluble precipitate.

*Sulphuretted* hydrogen gas is often found in mineral

water. It may be detected by carbonate of lead, on the addition of which, when the gas is present, a dark tint will show itself.

Chloride of sodium, or common salt, is also an ingredient of some water. This, together with muriatic acid, can be found out by nitrate of silver. The precipitate thrown down, by exposure to light, soon turns black.

Carbonate of lime, or chalk, being insoluble, is never found in water; but when an excess of carbonic acid is present, the bicarbonate resulting is soluble, and is very commonly met with. Boiling some of the water will drive off the excess of carbonic acid, and the chalk will at once make its appearance in a thick cloud. It is this which occasions the fur on tea kettles and boilers, where this description of water is used. Salts of lime are readily detected by oxalate of ammonia; also, when the quantity is great, by adding carbonate of soda. Ferro-prussiate of potash will make known the presence of salts of iron; and with salts of lead, the metal will be precipitated slowly by a piece of zinc, or form a white precipitate with sulphuric acid. Nitrate of barytes will detect sulphuric acid. Salts of potash may be found by bichloride of platinum, which will form a yellow crystalline powder. Soda, which has properties similar to potash, differs from it in not forming a precipitate with the above mentioned test.

According to the quantity and nature of the foreign matters found in water, so has it received certain names indicative of its character. Thus, saline waters are those that contain salts of soda, lime, or magnesia, &c., the combination generally being with sulphuric and muriatic acid. Chalybeate waters usually contain either carbonate or sulphate of iron. Many such springs of water are found; Tunbridge Wells, for instance. Sometimes the chalybeate and saline properties are combined. Such a compound water as this is found at Cheltenham. Acidulous waters contain much free acid, usually carbonic, which imparts to it a sparkling character. At times, the acid is muriatic or sulphuric. Sulphureous water abounds in sul-

phuretted hydrogen gas. It is often used medicinally, and is extremely unpalatable. The waters of Harrogate are of this class.

The above tests will at once show the character of any proposed water, and by evaporating a quantity to dryness, and weighing the solid residue, the quantity of earthy matter may be arrived at. For the purpose of dissolving out, in hot water, the properties of immersed substances, the softer the water is the better; but when it is only to soften and but slightly change the character of any substance, as, for instance, in cooking vegetables, hard water is superior; it prevents the colouring matter and properties of them being abstracted. This is owing either to the direct chemical action of the salts, or by their occupying the spaces between the pores of the liquid. Some water may be kept with impunity in leaden vessels; with others the attempt is highly dangerous. Acids act upon lead; but with sulphuric, arsenic, hydrodic, and phosphoric, a crust is formed on the surface of the metal, which thus protects the lead from further action. Water charged, therefore, with these acids, may safely be kept in lead; but if the acid be carbonic, the result is very different; the crust is not a protecting one, but mixes with the water as fast as it is formed, thus leaving a clear surface of lead always ready to be acted upon, and disseminating through the mass of water a poisonous salt of lead.

# APPENDIX.

THE description of the following Example is considered well
worthy of remark, as it tends to show the great advantage
arising from a plentiful supply of water, together with the
ease with which it is often obtained in districts apparently
wanting in that necessary article.

At Bulphan Fen, within a few miles of Aveley, Essex, is
a large tract of grass land, situated low, and liable to be much
flooded in the winter season.    Its value was little, as in the
summer time it was destitute of good water, being wholly
dependent upon the pools and ditches which retained the
remains of the winter's rain and floods.    This rendered it
unfit for stock, as, in addition to the small quantity of water
remaining, even that was rendered bad by the heat of the
weather.    The landowners in the neighbourhood were in-
duced to bore, and, being successful in finding springs, the
water from which overflowed the surface of the ground, their
example was followed by the proprietor of the Artesian well
under consideration, who, together with his father, suffered
much inconvenience from the scarcity of water upon 300
acres of low grass land at Aveley.    A spot was fixed upon at
the edge of the uplands, and about the level of high water
mark of the Thames; during the month of August, 1835,
the work was commenced.    The bore of the auger was 3
inches.    The first 5 or 6 feet were an alluvial soil, mixed with
many small stones, the whole of a gravelly nature; succeeding
this was a very soft, boggy ground, which ran in as fast as
bored out; into it was inserted wrought iron pipe of the usual

construction: the thickness of this bog was about 2 feet.
The next substance was light brown sand, very close, firm,
sharp, and fine; it became darker as the work proceeded, till,
at 65 feet from the surface, it was almost black. Separating
this sand and the chalk, was a small portion of light, grass
green, flaky rock. In the chalk were layers of flints;
and the boring was carried on in this formation about
35 feet, when the auger and rods suddenly dropped 7 feet
into a cavity of very soft, almost liquid, chalk, from which
the water rose to within 1 foot of the surface of the marsh;
water had been met with previously, but not in such large
quantities as this spring furnished; and, no doubt, the water
from this would have risen higher but for its connection with
other and weaker springs, which reduced its standing level
by abstracting a portion of the water instead of adding
thereto, which effect would be owing to the greater hydro-
static pressure of the lower and stronger spring; it must,
therefore, always be borne in mind that, where a great rise of
water is wished for from a deep strong spring, all others
should be very carefully blocked out; when quantity, and not
standing level, is the question, the features of the case are
altered. To return from this digression: the water in this
well, which, as before remarked, rose almost to the surface,
was conducted by a 2-inch pipe, inserted 3 inches under the
water level, into ditches traversing the land; the water ran
white for some days, but ultimately perfectly clear, and con-
tinues to run night and day. The temperature is 51° Fahr.
winter and summer, and the quantity delivered in 24 hours
about 30,000 gallons; it supplies 2 miles of ditches 10 feet
wide, from which it runs into the sea.

In the neighbourhood of the above Artesian bore are
situated some wells of the ordinary kind; the spring or
springs to which they are sunk are strong, the water rising to
the same level as in the Artesian one; they receive their
*supply* from the saturated sand spoken of above, and which
*is situated above* the chalk. The identity of level between

the wells is, no doubt, owing to their communication, which is established by the water from the chalk rising outside the pipe which lines the bore, the water naturally preferring such an exit to rising higher inside the pipe itself. Even with the most carefully executed work, it is difficult to prevent water rising outside the boring pipes where they pass through sand; therefore, in ordinary cases, such an effect may be expected to take place, unless the lower springs are separated from the upper by an impermeable collar of clay or other matter through which the pipe passes.

### Artesian Well, New Model Prison.

The annexed description of the well at the New Model Prison is taken from an excellent paper published in the work entitled " Papers of the Royal Engineers," Vol. VI., by Lieutenant-Colonel Jebb, under whose direction the work was carried on. The following specification was submitted for competition to several well-sinkers, their estimate and tenders being founded on it:—

" Specification for sinking an Artesian Well at the
Model Prison, Caledonian Road.

" To sink a well, so as to be 6 feet diameter in the clear within the brickwork, to the depth of 150 feet. The price for each succeeding 30 feet complete to be stated. To be steined with 9-inch brickwork, with malm paviors, the back steining to have three courses in cement at every 5 feet, and the double, or inner steining, to have four courses in cement at every 10 feet.

" The brickwork to be completed in successive portions of 5 feet, or less, if found necessary. The bricks to be of the best quality; the Roman cement to be mixed with one equal proportion of clean, sharp river sand. Should it be found necessary to sink to a greater depth (not exceeding 30 feet), the contractor will state in his tender at what price per foot he will execute the same, in every respect as above specified.

To fix 9 feet of 12-inch cast iron pipe at the bottom of the shaft, and to bore with a 10½-inch auger, and continue with the same down to the chalk, inserting in the bore cast iron pipes 8 inches diameter, and not less than five-eighths of an inch thick on the sides, fitted together with turned joints and wrought-iron collars, and fitted with screws: the whole to be flush inside and outside.

" To continue boring in the chalk, with a 7½-inch auger, to such depth as will secure good water from the main spring, and in such quantity as may be considered necessary.

" The whole of the above works are to be done in a workmanlike manner, with materials of the best description of their respective kinds, and to the entire satisfaction of the superintending officer.

" The contractor will state at what price per foot, or per 10 feet, including the iron pipes, he will bore until he reaches the chalk; and at what price per foot, or per 10 feet, he will bore through the chalk until the necessary quantity of good water is obtained.   Also at what price per foot he will provide and fix perforated copper pipes, 6½ inches diameter outside, weighing 6 lbs. per foot, in the chalk, as far as may be necessary.   The prices stated in the tender are to include every expense, the finding of all materials, scaffolding, tackle, cartage, &c., the stopping out the land springs in an effectual manner, and every expense requisite for the entire completion of the work, excepting the removal of the earth excavated. If pumps are required during the execution of the work, they are to be supplied by the contractor, together with labour in pumping, and troughs for carrying off the water, without extra charge.  Stone corbels, for supporting permanent framing, will be furnished to the contractor, to be inserted in the brickwork without extra charge."

The tender of Mr. Thomas Clark, of Tottenham, was considered as the most advantageous, and was, therefore, accepted.   The tender was as follows:—

"TENDER for sinking an Artesian Well at the
Model Prison.

"Tottenham.

"I hereby tender to sink a shaft so as to be 6 feet
diameter in the clear within the brickwork, to the depth of
150 feet, and to provide such materials as are required by
the specification, and to perform the work in every way
agreeably thereto; and to fix a 12-inch cast-iron pipe, 9 feet
long, at the bottom of the shaft, at the following prices:—

|  |  |  |  |  |  | £ | s. | d. |
|---|---|---|---|---|---|---|---|---|
| 1st 30 feet, for the sum of | | | . | . | | 67 | 10 | 0 |
| 2nd | do. | do. | . | . | . | 57 | 0 | 0 |
| 3rd | do. | do. | . | . | . | 58 | 10 | 0 |
| 4th | do. | do. | . | . | . | 60 | 0 | 0 |
| 5th | do. | do. | . | . | . | 61 | 10 | 0 |

Also to sink as many feet further as the superintending officer
may consider necessary, so as not to exceed 30 feet, for the
sum of £2 5s. per foot; also, to bore to the chalk with a
10½-inch auger, and fix pipes of the diameter required, and
fitted together as specified, for the sum of £2 2s. per foot;
also, to bore into the chalk with a 7½-inch auger to such depth
as may be considered necessary by the superintending officer,
for the sum of £1 7s. per foot; and if it should be determined
to insert perforated copper pipes in the boring in the chalk,
I hereby tender to supply the same, to weigh not less than
6 lbs. to the foot, and to fix the same in the bore for the
further sum of 10s. 2d. per foot; and in every other respect
to conform to the specification, and to complete the whole of
the work in a proper and workmanlike manner, and to the
satisfaction of the superintending officer.

(Signed) "THOS. CLARK.

"To Capt. JEBB, Royal Engineers."

In commencing the work five men were employed, who
made an excavation 9'·6" diameter, which was to allow space
for the finished shaft to be 6'·0" in the clear, with the 9-inch

steining, and 12 inches of puddle at the back, for more effectually excluding the land springs. This excavation was carried down to the depth of 10 feet. The 9-inch steining in cement and the puddle were then commenced, and completed to the surface. The stratum of clay at this depth was so solid, that it was considered that the puddle might be dispensed with; an excavation only 7 feet 6 inches in diameter, and 5 feet deep, was therefore made, and the back steining only of half a brick in thickness, completed in cement. Similar excavations of 5 feet in depth were made in succession, the back steining alone in each case being completed, until the solid mass of London blue clay was found, at the depth of 30 feet from the surface. The inner steining was then brought up in cement, so as to underpin the first portion which had been completed. The land springs were found to be effectually excluded, and the work then proceeded in all respects according to the specification. Two additional hands were employed when the well was about 30 feet deep, and no difficulty was experienced until the mass of London clay was cut through, and the upper beds of the plastic clay formation, which were found at the depth of 150 feet, were perforated. Here a stratum of dark sand was found, containing a little water. This sand was so loose that it did not afford sufficient foundation for the brickwork; and there was this further difficulty, that had the water been pumped out, the sand would have been set in motion, or, to use a technical expression, would have blown up in the well. Under these circumstances, it was determined to substitute cast-iron cylinders, 5 feet in diameter and 1 inch thick, for the brick steining.

The specification and tender for supplying the cylinders, and executing the work with them, was as follows:—

"TENDER for supplying cast-iron cylinders to be used
in lieu of steining.
"Tottenham.
"*I hereby engage* to secure the present brickwork in its

place by strong elm ribs, suspended by iron rods up the shaft, and to provide and fix cast iron cylinders of 5 feet diameter and 1 inch thick, in 5-feet lengths, with internal flanges, properly packed and bolted together, and to caulk the same with iron cement, and to carry them down through the upper sand, and drive the lower end firmly into the clay ; and to concrete behind the upper cylinder with gravel and cement, to form a footing for the lower steining, and for stopping out water, providing every material required for the work, at £7 2s. per foot lineal. (Signed) Thos. Clark."

Before proceeding to lower the well or fix the cylinders, it was necessary to secure or tie up the brickwork which had been already executed. For this purpose a strong elm frame was inserted under it, and the frame being connected by 1¼-inch rods, with 2 strong beams fixed over the top of the well, effectually secured the steining in its place. In order to steady the cylinders, and keep them in a right line as the work proceeded, four battens, 20 feet long, 7 inches wide, and 2½ inches thick, were fixed to the lower part of the brickwork, forming a kind of frame through which the cylinders would slide ; this being arranged, the first cylinder, 5 feet in length, was lowered to the bottom, and, after being properly adjusted by means of wedges, another was added on the top, and the joint of the flanges made good ; four others were added in succession, making a length of 30 feet of cylinders fixed, before the excavation was proceeded with. The object of this was twofold ; first, that the outer surface of the cylinders being confined within the wooden frame already described, the true direction would be maintained ; and, secondly, that the weight of the mass would aid in its descending into its place as the boring or excavation was proceeded with ; by these means, had the stratum proved to be a quicksand, the difficulty would have been overcome ; a stage was then placed on the upper part of the cylinders, and an auger, 4'·10″ in diameter, was introduced within them.

Each time that this auger was drawn out, the cylinders settled on an average about 2 inches, and no difficulty was experienced. The stratum of sand, which was about 20 feet in depth, was cut through, and a hard mottled clay was found under it; it was essential that the cylinders should be firmly fixed in the clay, in order to prevent the water contained in the sand from forcing its way under them, and rising into the well. The boring was therefore continued for a few feet, and the cylinders were at last driven into the clay with a heavy dolly, made of the rough trunk of a tree. The water, which had hitherto stood above the level of the top of the sand in the cylinders, was now pumped out, and the well remaining perfectly dry, afforded evidence that the water contained in the sand had been effectually stopped out. The 12-inch pipe mentioned in the original specification was dispensed with, and the boring was continued with a 10½-inch auger down to the chalk; 8-inch pipes were then introduced, which were firmly fixed several feet into the chalk, and were left standing 6 feet above the bottom of the cylinders. The object of this latter arrangement was, that any sediment contained in the water would settle at the bottom of the well."

The following is a section of this well, together with the distance from the surface of the ground to various points in the well itself:—

| | ′ | ″ |
|---|---:|---:|
| Yellow clay and gravel . . . . | 30 | 0 |
| Blue clay . . . . . | 100 | 0 |
| Mottled clay . . . . . | 19 | 6 |
| Dark loamy sand and little water . . | 18 | 0 |
| Hard mottled clay and sand, without water | 17 | 0 |
| Dark sand, with little water . . . | 34 | 0 |
| Hard flint . . . . . . | 1 | 0 |
| Chalk . . . . . . | 151 | 0 |
| Total depth . . . . | 370 | 6 |

Distance of bottom of brick shaft to surface 153   0

    ,,     from top of iron cylinders to do. 139  0

    ,,     from bottom of iron cylinders to do. 170  0

    ,,     from bottom of iron piping to do. 230  0

    ,,     from top of copper piping to do. 220  0

    ,,     from bottom of copper piping to do. 259  0

On the completion of this well, it was considered desirable to test the strength of the spring by pumping, which operation had also the effect of freeing the sides of the bore, thereby allowing the water to percolate quicker, for the action of the tools necessarily had a tendency to harden the chalk. The pump was kept at work night and day; a relieving gang of men coming on every four hours. After working in this manner for 48 hours, the level of the water in the cylinders was marked, and it was also ascertained that in one hour rather more than 900 gallons were removed from the well. The water level was lowered by the pumping one foot; and as a hole 5'·0" in diameter and 1 foot deep, contains 122 gallons (see page 38), that amount deducted from 900, gives as the water supply nearly 800 gallons per hour

CROSS SECTION OF PART OF THE LONDON BASIN.

FROM F TO A. PLATE 3.

Harrow on the Hill.

Thames.

London Clay.
Plastic Clay and Sand.
Upper Chalk.
Lower Chalk.
Chalk Marle & Fire Stone.
Blue Marle.
Green Marle.
Green Sand.
Blue Marle.
Iron Sand.

Botley Hill.

Vale of Holmesdale.

Crowborough Hill.

Iron Sand.
Blue Marle.
Green Sand.
Lower Chalk.
Chalk Marle.
Upper Chalk.

Newhaven.

Plastic Clay.

The Sea.

*Pl. 4.*
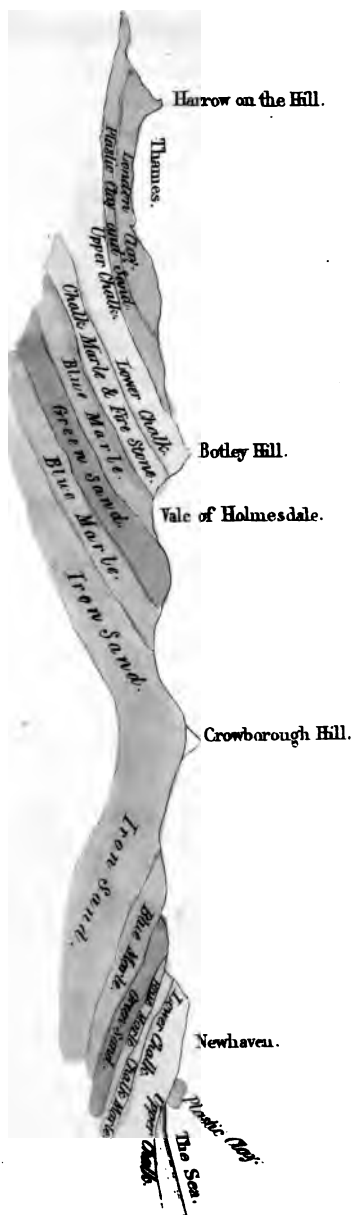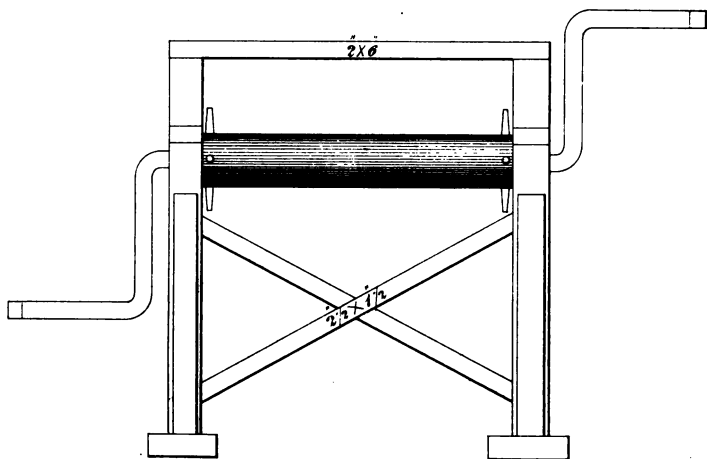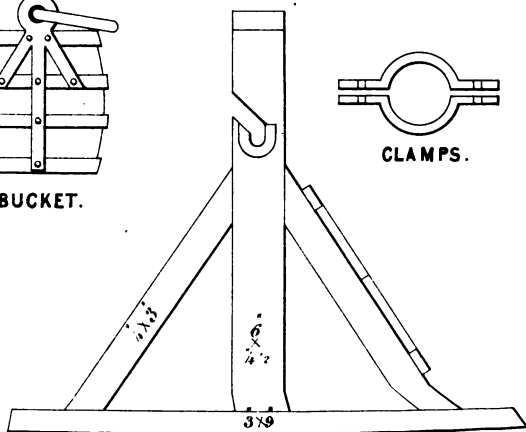


FRONT VIEW OF WINDLASS.



BUCKET.



CLAMPS.



HOOK.



SIDE VIEW OF WINDLASS.
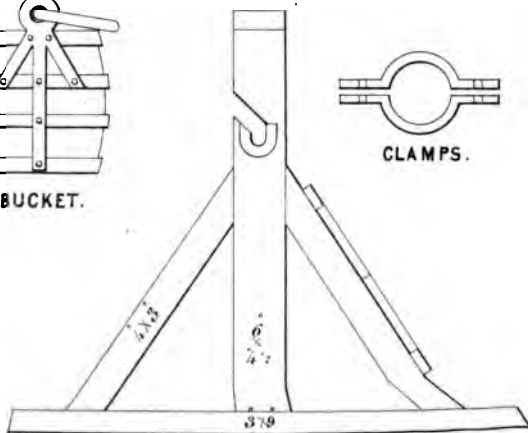
*Pl. 4.*

$\overline{2 \times 6}$

$2\frac{1}{2} \times 1\frac{1}{2}$

**FRONT VIEW OF WINDLASS.**

**BUCKET.**

**CLAMPS.**

**HOOK.**

$4 \times 3$

$\frac{6}{4}$

$3 \times 9$

**SIDE VIEW OF WINDLASS.**

.

.

FIG.7.

FIG.5.

FIG.II.

FIG.8.

FIG.4.

FIG.I.

FI·

FIG.3.

FIG.2.

*a·*

FIG.9.

FIG.10.

FIG.7.

FIG.5.

FIG.II.

FIG.4.

FIG.8.

FIG

FIG.I.

FIG.3.

FIG.2.

a.

FIG.9.

FIG.10.

114
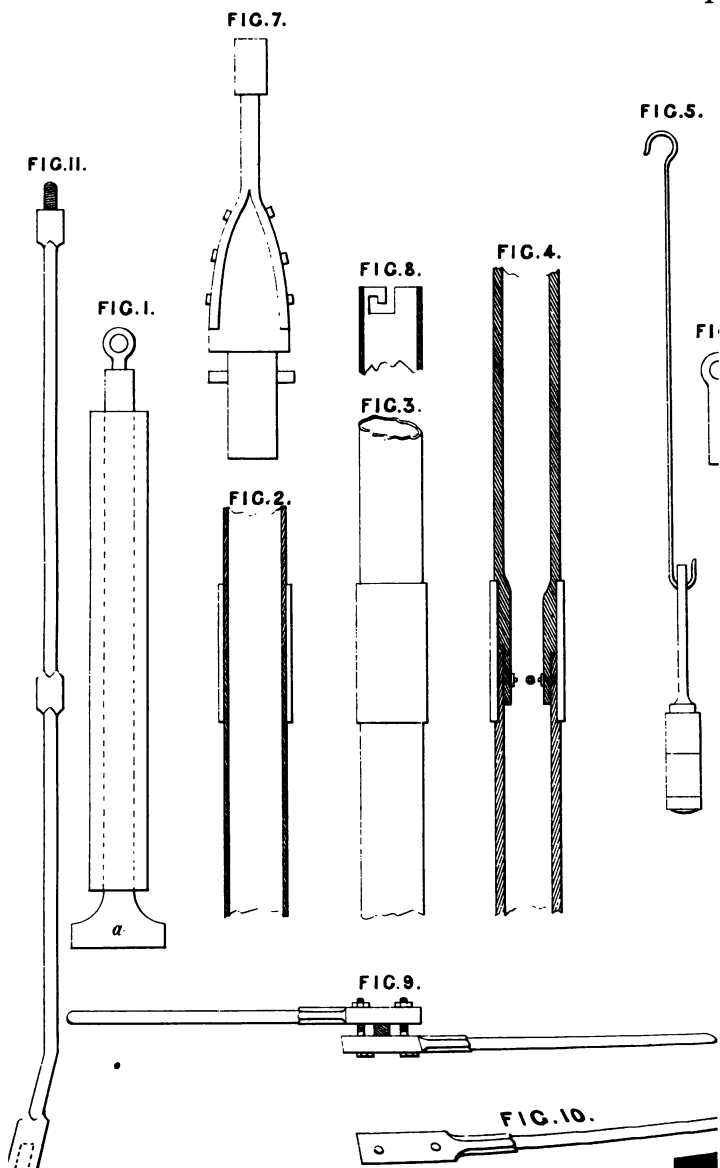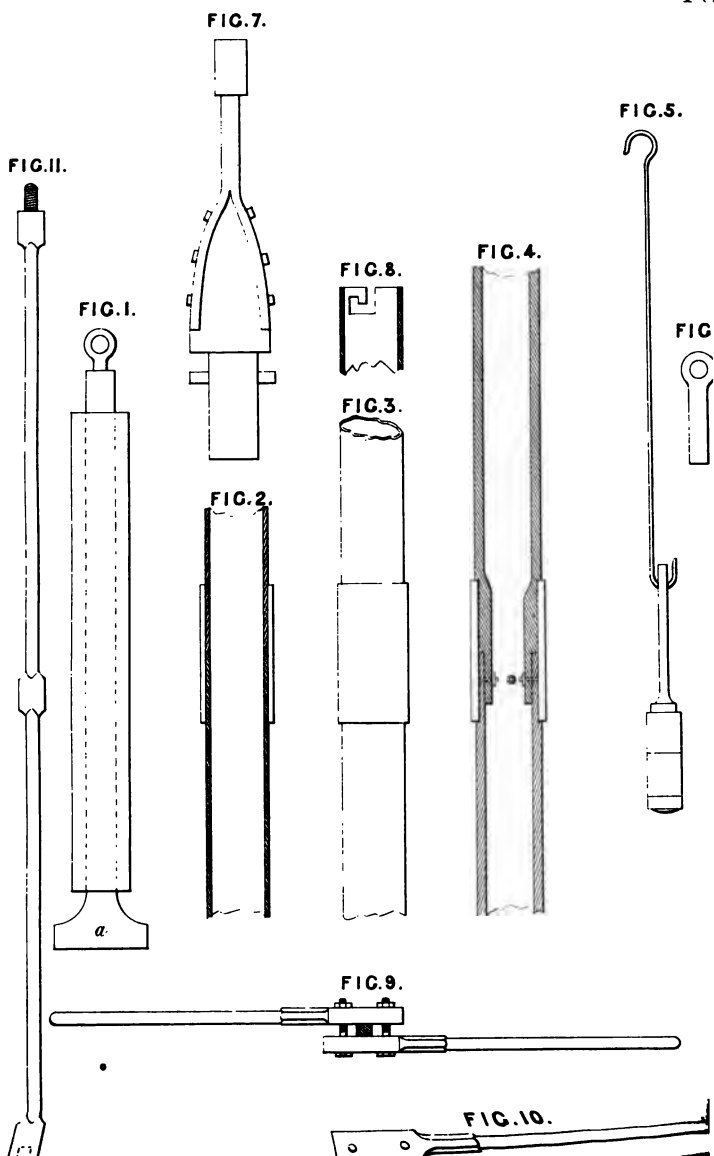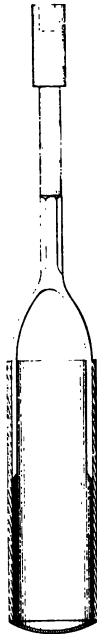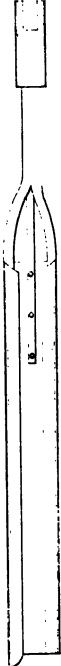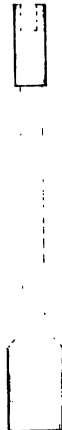
FIG.I. FIG.2. FIG.7. FIG.9. FIG.II.
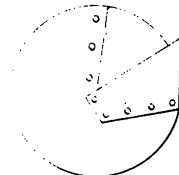
FIG.3.
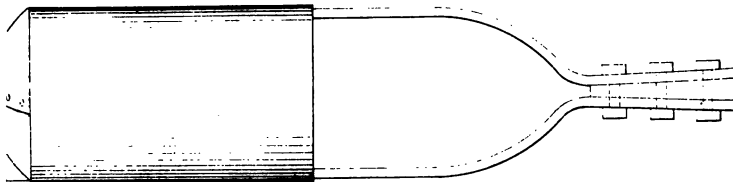
FIG.10.
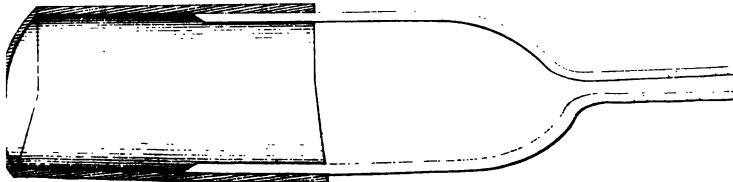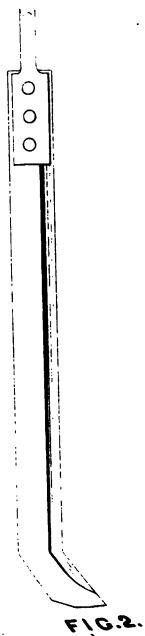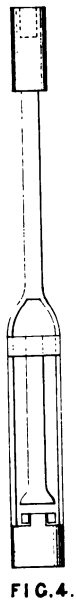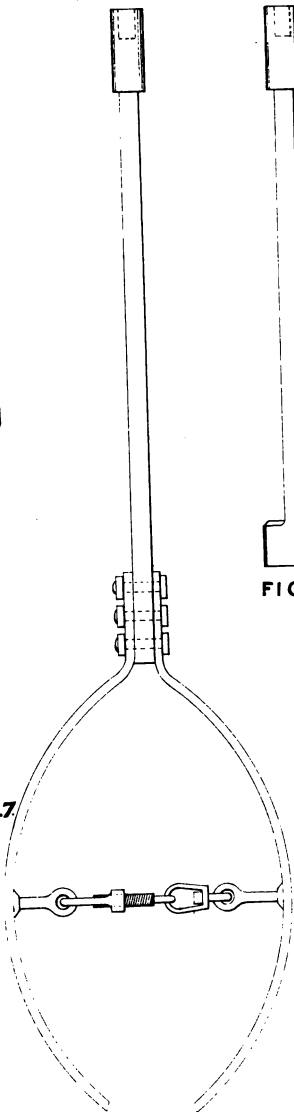
FIG.6.

FIG.8.

FIG.4.

FIG.5.

FIG.1.

FIG.2.

FIG.3.

FIG.4.

FIG.5.

FIG.6.

FIG.7.
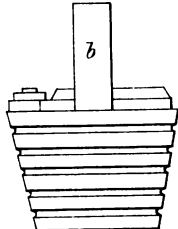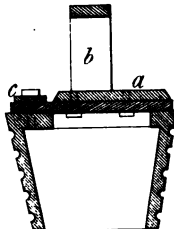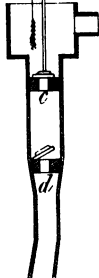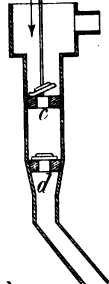
*Pl. 10.*



FIG.I.

FIG.2.

FIG.3.

FIG.4.

FIG.5.

FIG.7.

*b*

FIG.6.

*c*

*a*

FIG.8.

*c*

*b*

*a*

FIG.9.

*c*

*d*

FIG.10.

*c*

*d*

Scale for Details.

Inches

Pl. 1

FIC.2.

FIC.4.

FIC.3.

FIC.1.

a

b

Scale.

Inches                                                          Feet.

FIG. 2.

FIG. 4.

FIG. 3.

FIG. I.

*a*

*b*

c

c

*Scale.*

*Inches* 0 1 2 3 4 5 6 1 2 3 *Feet.*

.

Pl. 1.

FIG. 1.

C

F

E

B

A

D

a

a
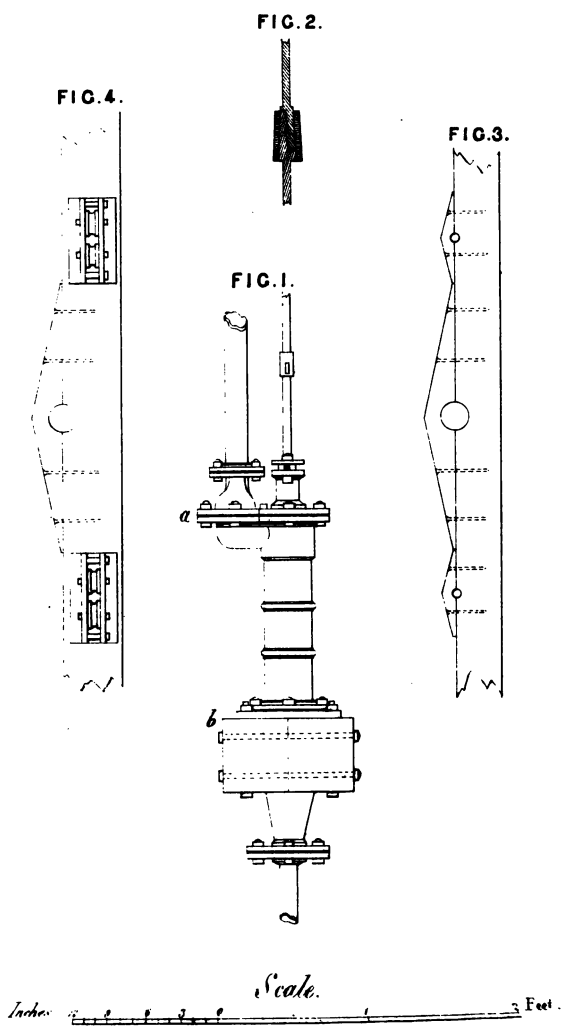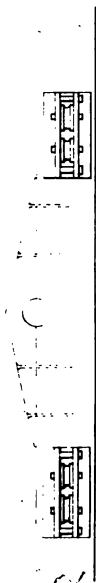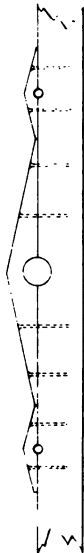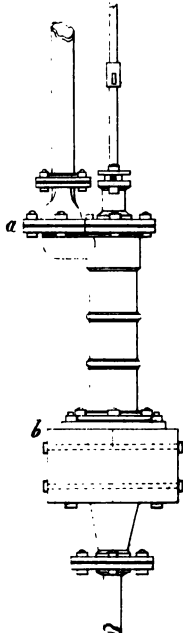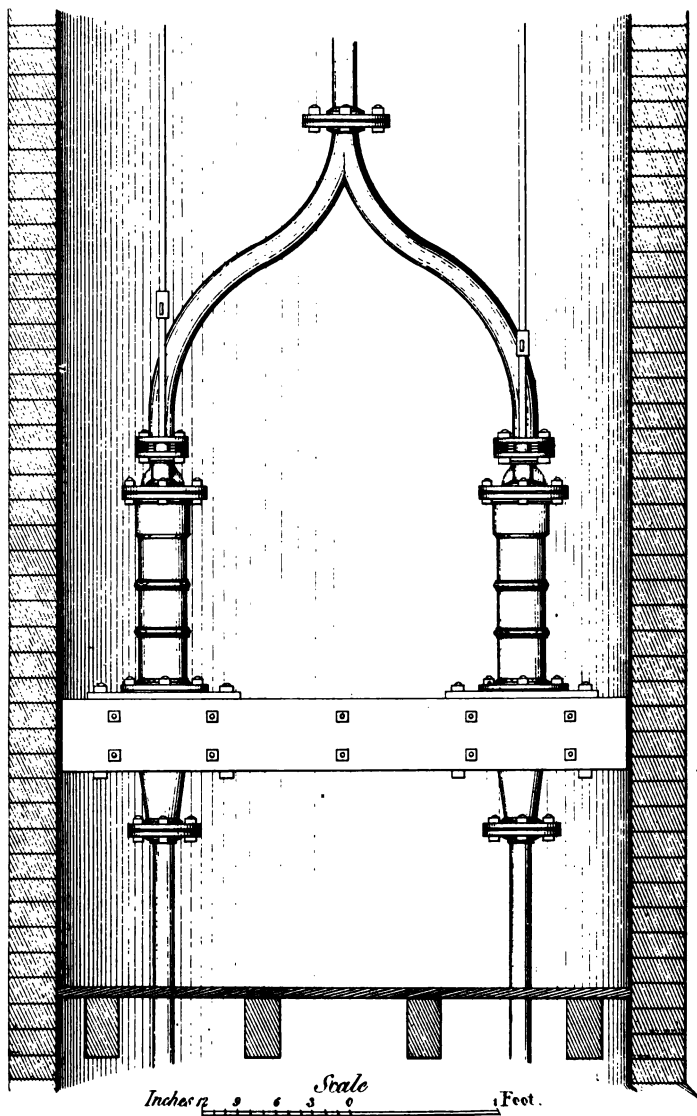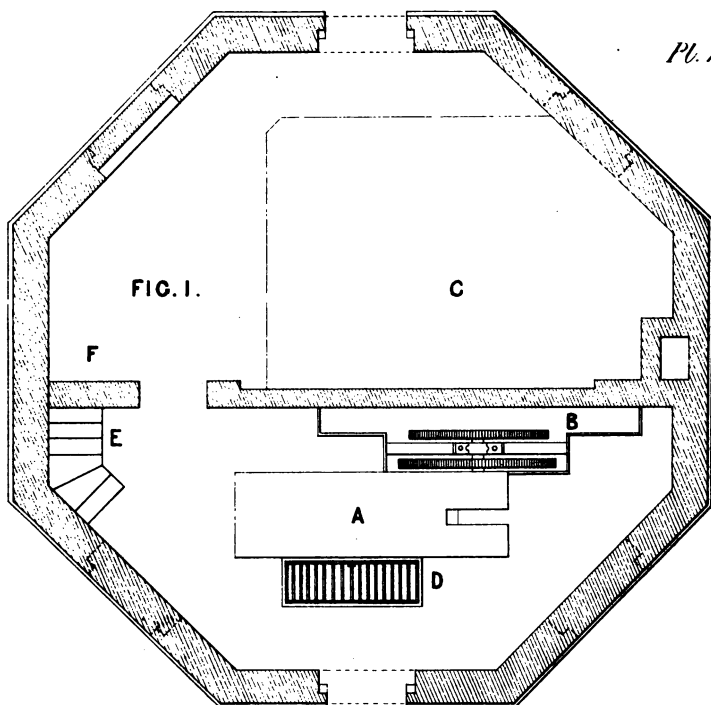
THE PLAN
OF
ENGINE HOUSE
HAMPSTEAD.
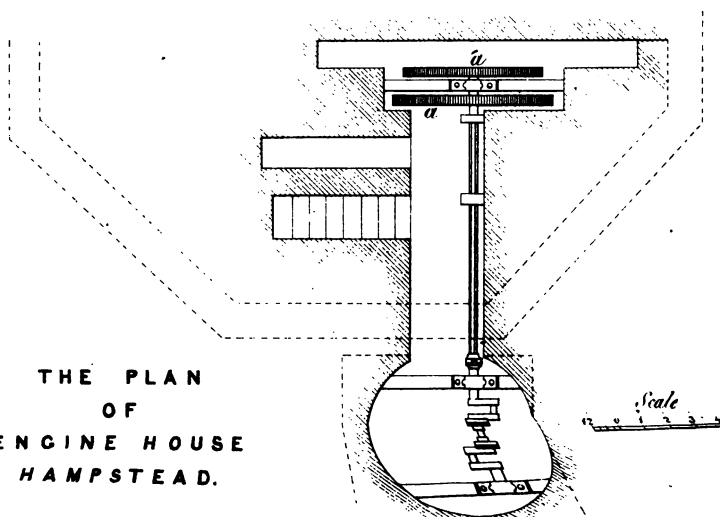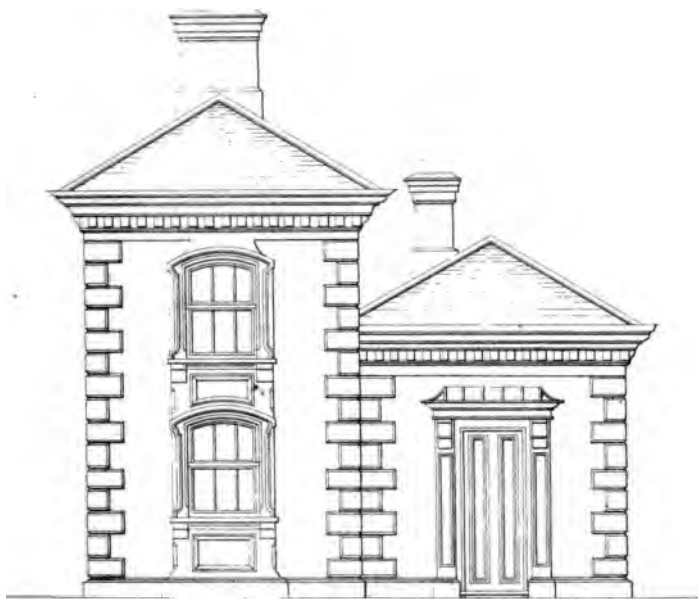
Scale

THE  ENGINE  HOUSE  KINGSBURY.

*Scale*

10         5          0                    10Feet

*Pl.16.*

# PLAN OF ENGINE HOUSE,
## KINGSBURY.



W.C.

COALS.

SCULLERY.

ENGINE

ROOM.

LIVING

ROOM.

OFFICE.

SCALE.

10            5            0                    10

*Pl. 1*

**SIDE ELEVATION.**

SCALE.

INCH 28 12          6          0          1 FOOT
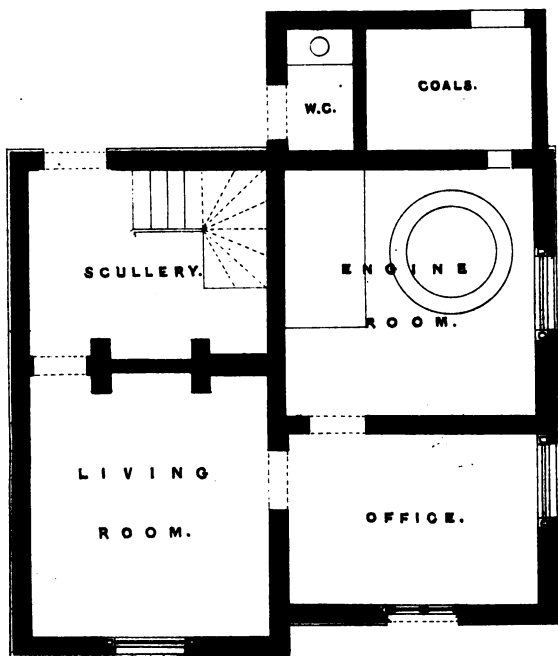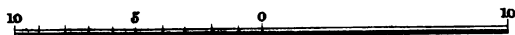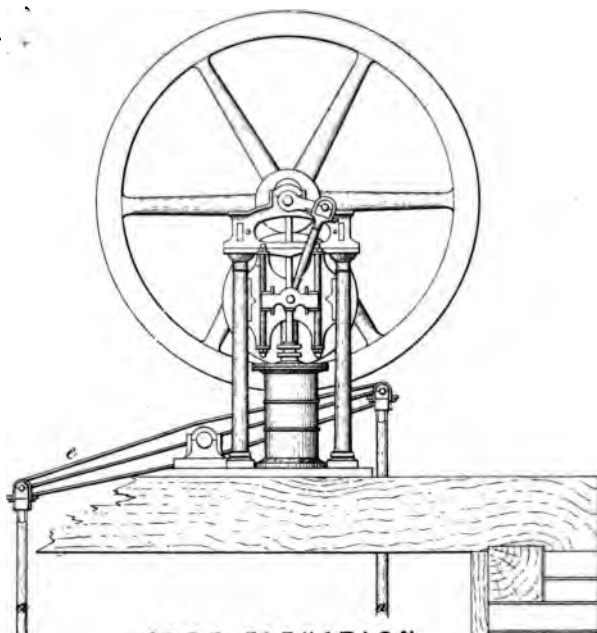
SMALL STEAM

ENGINE

FOR WORKING

TWO PUMPS.
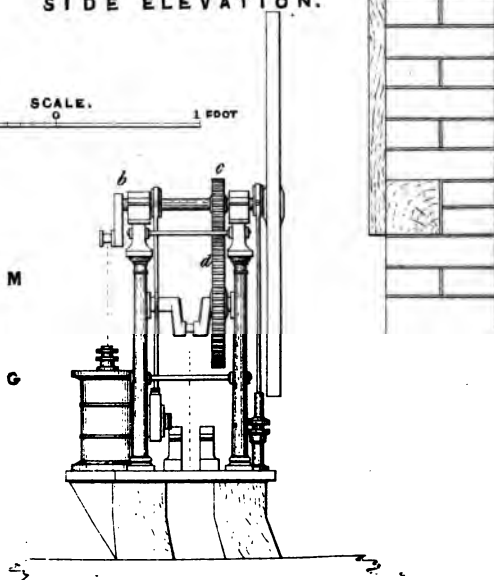
**END ELEVATION.**

SECOND SERIES

OF

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*A portion already published—the others in preparation.*